A PRELIMINARY DIAGNOSTIC STUDY OF ANDERSON PARK LAKES
MADISON COUNTY, INDIANA

A Report for
Parks and Recreation Department
Planning Department
City of Anderson

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Lake and River Enhancement Program

Division of Soil Conservation
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PRELIMINARY STUDY OF ANDERSON PARK LAKES

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PRELIMINARY DIAGNOSTIC STUDY OF ANDERSON PARK LAKES

EXECUTIVE SUMMARY

The region around the White River through Anderson has a unique human and natural history. Mounds State Park commemorates a long history of human settlement in the area along the river. The streams and adjacent forested areas support rare species even though development has progressed rapidly in some areas. Sand and gravel mining operations have used resources generated by past glacial activity along the river, changed the present day landscape, and left water for recreation and conservation in their path. The City of Anderson has taken the initiative to protect remaining areas with natural and cultural value around the formerly mined areas.

Shadyside Park Lake (formerly Aqua Gardens) and Vulcan Lake were created by abandoned gravel pits that are currently in possession of the Anderson Parks and Recreation Department. The department has administered, developed and maintained these facilities within the City of Anderson as recreational sites. Shadyside Park contains two abandoned gravel pits joined by a channel within the Anderson City limits. Together the lakes cover about 63 acres with a maximum depth of 40 ft in the south basin, an average depth of 20 ft, and containing 1,000 acre-ft of water. The combined watershed encompasses 2,433 acres. A gravel pit in the floodway of the West Fork of White River just west of Mounds State Park forms Vulcan Lake. The lake has a surface area of approximately 8.7 acres. No maximum depth was available, but the lake is at least 10 ft deep. The watershed covers 302 acres.

Shadyside Park Lake has an intermediate surface area and depth and shows moderate to advanced eutrophication. Water quality problems are generally "not severe enough to warrant drastic restoration techniques" but the "main management priority, which will improve water quality most effectively on both a short and long term basis, is the limitation of nutrient inputs" (IDEM, 1986). Vulcan Lake is a shallow lake with relatively high water quality, due to its origin as a recently formed gravel pit and forested surrounding land use. Shallow lakes do not have a large volume of deep water to buffer pollutant response, so they tend to degrade quickly and dramatically from pollution. Management priorities stress maintenance of present conditions.

Artificial restoration methods such as aeration and alum treatments may be warranted for Shadyside Park Lake, but are also expensive and require monitoring. Spot dredging may be useful, especially in the delta that has formed at the mouth of Shady Run. Reshaping the shoreline in Shadyside Park Lake could provide additional shallow areas for wetland and aquatic plant development. By identifying watershed sources of sediment, encouraging appropriate land use, and properly maintaining sediment and stormwater detention basins, restorative measures should not need to be repeated. Development of a sediment basin within Shady Run in the area just upstream of the inlet where materials mining is currently located would treat pollution from upstream activities. Design of the basin to include a pool and wetland complex would increase benefits to water quality, wildlife habitat, and aesthetic appeal.

Fisheries management could be employed in several stages, starting with habitat management and continuing with direct manipulation of the fish community. Redistribution of oxygen into deeper water would provide fish habitat and reduce water quality problems related to nutrients and hydrogen sulfide in deeper water of Shadyside Park Lake. Use of an aerator to completely destratify the water column would distribute oxygen throughout the lake, but could also resuspend harmful levels of nutrients that may currently remain unmixed at the bottom of the lake. Because Vulcan Lake was created as an isolated water body, the fishery should be assessed and successfully improved through stocking, if necessary. Storage and use of road salts near lakes and their tributaries should be prohibited or carefully controlled.

Rapid development emphasizes the importance of the city parks in Anderson for conservation of wildlife habitat and human recreation. The occurrence of rare species on nearby state park land indicates the potential for significant habitat development in the areas around the lakes. Plant management within the park areas should be a priority. Management of the area to prevent intrusion or expansion of exotic invasive species like Amur honeysuckle (*Lonicera maackii*), multiflora rose (*Rosa multiflora*), purple loosestrife (*Lythrum salicaria*) or garlic mustard (*Alliaria officinalis*) should continue. Maintenance or development of walking paths or access sites around the lake should include attention to erosion control and retention of a buffer zone of native vegetation along the water. Interference of aquatic plants with recreational use should be monitored in all study lakes with particular attention to Vulcan Lake.

Further water quality and biological monitoring could provide additional information on effects of seasonal changes, extreme weather, and rapidly developing land use. Seasonal readings with a Secchi disk in dry and wet years would inexpensively provide further information regarding the source of turbidity in the lakes. The historical and current presence of numerous mussels in Killbuck Creek suggests that these populations should be monitored and may warrant additional protection from water quality degradation.

The dramatic increase in population in Anderson over the past 30 years has probably had a detrimental effect on water quality in the streams and impoundments in the area. The strong relationship in both basins of Shadyside Park Lake between monthly precipitation and water clarity from 1975 to 1996 indicate that watershed land use significantly influences lake water quality. If adequate land use management is not implemented, these waters will continue to degrade.

In the Shadyside Lake watershed, the few remaining crop fields and areas currently undergoing mining will presumably be available for residential or park development in the near future. Rural uses, such as agriculture and mining, are probably temporary, but should still be conducted with proper land management measures to reduce soil erosion and chemical runoff.

Developments around the lakes must use appropriate soil stabilization measures during and after construction to protect water quality. Incorporating forested landscapes into developments can increase property values, as well as improving wildlife habitat and water quality. Adequate bank stabilization and maintenance of vegetation around retention ponds and along stream corridors will improve habitat and recreational value.

1.0 INTRODUCTION

Shadyside Park Lake (formerly Aqua Gardens) and Vulcan Lake were created by abandoned gravel pits that are currently in possession of the Anderson Parks and Recreation Department. The department has administered, developed and maintained these facilities within the City of Anderson as recreational sites.

1.1 Shadyside Park Lake

Shadyside Park contains two abandoned gravel pits joined by a channel within the Anderson City limits. Together the lakes cover about 63 acres with a maximum depth of 40 ft in the south basin, an average depth of 20 ft, and containing 1,000 acre-ft of water. The combined watershed encompasses 2,433 acres (Figure 1). Lake surface area has fluctuated over the past several decades, but is about 20 acres in the North Basin and 43 acres in the South Basin and adjacent ponds. The North Basin is at least 14 ft deep, although there was no available record of maximum depth. The water level fluctuates approximately 2-4 ft around the mean water level of 832 ft elevation. Two unnamed pipes (one in each pit) provide overflows between Killbuck Creek and the lakes. Shady Run, a small intermittent stream, enters the upper lake (North Basin) from its origin one mile east of the lakes. An earthen spillway into Killbuck Creek maintains the lake level at the south edge of the lower lake (South Basin). The bottom of the lake consists of gravel and sand.

The current primary use of Shadyside Park Lake is as a public recreational resource for fishing, boating, and pedestrian traffic. Shadyside Park Lake is surrounded by paved trails and equipped with a boat ramp. The trail allows fishing at almost any location along the shoreline. The parks department was concerned about pollution from overpopulation of domestic ducks and the lack of lake oxygenation that was noted in several fisheries studies (Jim Haberek, LARE application, January 31, 1996). The Fisheries Section of the Indiana Department of Natural Resources (IDNR) conducted fisheries surveys in 1972, 1975, 1976, 1977, 1979, 1991, 1994, and 1996.

Public dock at north end of Shadyside Park Lake.

Figure 1. Watershed area for Shadyside Park Lake along Killbuck Creek in Anderson, Madison County, Indiana.

1.2 Vulcan Lake

A gravel pit in the floodway of the West Fork of White River just west of Mounds State Park forms Vulcan Lake. The lake has a surface area of approximately 8.7 acres. No maximum depth was available, but the lake is at least 10 ft deep. The watershed covers 302 acres (Figure 2). Access to Vulcan Lake is owned by the parks department and will be opened to the public upon completion of a park management plan. The main access road will be Range Line Road north of White River. The parks department was concerned about extensive surface algae that may impede fishing habitat and improvement of the lake and surrounding area for healthy diversity of aquatic life and to enhance plant and animal life. Previous studies of the lake have been conducted by Tamera Doty, landscape architect and city forester, the staff of the parks department,
interns at Ball State University, biology classes, and high school teachers (Jim Haberek, LARE application, January 31, 1996).

View of Vulcan Lake from public access point near C.R. 200 East.

2.0 METHODS

Watershed maps for topography and forested land use were redrawn or copied from the most recent (1981, 1988) U.S. Geological Survey 7.5 minute topographic maps at a scale of 1:24,000 (Anderson North, Anderson South, Middletown, and Gilman quadrangles). Data on land areas was calculated from aerial photographs taken in 1939, 1956, and 1961 which are on file at the Indiana State Archives, Commission on Public Records. Aerial photographs in the Madison County Soil Survey provided information for 1959-61 along with topographic maps adding revisions in 1981 and 1988. Ground surveys were conducted in 1997. Soil maps were derived from the Madison County Soil Survey. The amount and location of highly erodible soils (HEL) was calculated from land area measurements based on grid overlays of the soil maps.

Figure 2. Watershed area for Vulcan Lake along the West Fork of the White River, Anderson, Madison County, Indiana.

Water samples and in-lake measurements were obtained during late summer on August 6, 1996, at the deepest point of the basins of Shadyside Park Lake and Vulcan Lake (Figure 3). All parameters needed to calculate the Eutrophication Index (EI) were measured or estimated. This index was developed by the Indiana Department of Environmental Management (IDEM) to classify the water quality status of lakes. Calculation of the index is described in the Appendix. One percent light depth was estimated as 2.7 times Secchi depth for the Anderson Park lakes (after Cole, 1983).

Profiles of temperature and dissolved oxygen were obtained with a YSI Model 51B Dissolved Oxygen Meter. Dissolved oxygen was measured using the Hach Surface Water Test Kit Model 25598-00. Nitrates, ammonia, total phosphorus, organic nitrogen (Total Kjeldahl Nitrogen or TKN), conductivity, turbidity, pH, and ortho-phosphorus were tested or preserved within four hours of collection from samples placed on ice in the field. Laboratory tests were conducted at the Indiana State Department of Health (ISDH).

Plankton samples were collected on August 6, 1996, over the deepest part of the lakes with a 12 in (30 cm) diameter, 63 micron mesh tow net. Two separate tows were taken, one from a depth of 5 ft (1.5 m) and another from the beginning of the thermocline at 9 ft (2.7 m).

Data on flora and fauna in the Shadyside Park and Vulcan Lake region were from several sources. The IDNR fisheries biologists made qualitative observations about aquatic plant growth. No direct sampling of aquatic plants was conducted. Data on the fish community were taken directly from fisheries reports submitted by Edward R. Braun, Tri-lakes Fisheries Station, IDNR. Data on threatened, endangered and rare species were from the Indiana Natural Heritage Database (Ron Hellmich, November 21, 1997, Division of Nature Preserves, IDNR).

Tributaries to Shadyside Park were sampled at four sites under baseflow conditions on May 2, 1997 and for stormflow conditions on May 29, 1997. Two sites along Killbuck Creek were tested: 1) above Shadyside Park on the north side of North Road; and 2) below the park where Rose Road is perpendicular to Killbuck Creek. Shady Run samples were taken at two sites: 1) about halfway up Shady Run on the east side of Highway 9; and 2) at the outlet of Shady Run.

Data on precipitation and peak flow in the Anderson area was obtained from various state and federal sources for comparison with water quality in the lakes. Precipitation measurements in hundredths of an inch by month and total were available for the Anderson Sewage Treatment Plant (Station #120177) for the years 1895 to 1987 on the internet from the NOAA National Climatic Data Center (NCDC) indexed at the following URL:

http://www.ncdc.noaa.gov/cgi-bin/res40.pl.

Figure 3. Locations for tributary water samples and in-lake measurements at Shadyside Park and Vulcan Lake, Madison County, Indiana. (1 = upstream on Killbuck Creek; 2 = inlake at North Basin; 3 = inlake at South Basin; 4 = downstream on Killbuck Creek; 5 = Shady Run near the outlet; 6 = Shady Run at Hwy 9. INSET: 7 = isolated drainageway near Vulcan Lake; 8 = inlake at Vulcan Lake)

Peak Flow Data was available for the White River at Anderson, Indiana (Station #03348000) for the years 1904 to 1993 from the US Geological Survey (USGS) at the following URL:

> http://waterdata.usgs.gov/nwis-w/IN/data.components/peak.cgi?statnum=03348000&bdate_year7/22/98edate_

For reference, peak flow data was also retrieved from the USGS internet site for Killbuck Creek near Anderson (Station #03348100) for the years 1964 to 1968. Monthly precipitation was correlated with water clarity in the North and South Basins of Shadyside Park Lake. Population census data was acquired from the US Census Bureau Tiger maps indexed at URL:

> http://www.census.gov/cgi-bin/gazetteer?city=Anderson&state=IN&zip=

An internet accessible application database of floodway permits, that are under review or were completed during the last 10 years, is available from the Indiana Department of Natural Resources (IDNR) Division of Water web site indexed at:

> http://www.ai.org/dnr/water.

Information on permits for Killbuck Creek, Shady Run, and the public lakes was obtained from this database.

3.0 WATERSHED CLIMATE, SOILS, AND LAND USE

Watershed geology, soils, climate, and land use are primary factors in determining the water quality status of lakes located in Madison County. The watersheds of Shadyside Park and Vulcan Lakes are contained completely in the county. All information regarding climate and soil formation and associations is taken directly from the Madison County Soil Survey, issued in 1967.

Central Indiana lakes are subject to four distinct seasons and significant precipitation. The climate of Madison County is continental with an average of 38 inches of precipitation per year, including 20.3 inches of snow or sleet. Precipitation in any one month ranges from an average of 1.9 inches in February to 4.1 inches in May and 4.0 inches in June. Maximum average snowfall occurs in January at 5.3 inches. Total yearly precipitation at the Anderson Sewage Treatment Plant for the years 1895 to 1987 ranged between 29 and 55 inches (Figure 4). Average temperature ranges from 29^{o}F in January to 75^{o}F in July, with a minimum of –20^{o}F and maximum of 105^{o}F. The highest probability of freezing temperatures extends from November 5 to April 11 with an average growing season of 178 days. The highest elevation in Anderson is 874 ft. A detailed account of the soil development, associations, erodibility, and current land use follows.

Figure 4. Total annual precipitation at the Anderson Sewage Treatment Plant Lake, Madison County, Indiana, from 1895 to 1987 from the NOAA National Climatic Data Center.

3.1 SOIL TYPES AND LIMITATIONS

The soils of Madison County formed in glacial till, or ice-laid material, and water-laid deposits, or alluvium. Glaciation has been a significant factor in development of Madison County soils. Ice sheets, which were hundreds of miles long and thousands of feet thick, covered the county at least three times. Rock, sand, silt, and clay were left in a flat plain when ice sheets melted or receded. The resulting relatively flat uplands are part of the Tipton Till Plain. Since glaciation, streams have cut valleys up to 40 feet deep into the glacial drift. The White River through present day Anderson was a subglacial stream that deposited sand and gravel that now form terraces along the stream.

A soil association describes an area that contains a distinct pattern of soil types. It normally includes one or more major soils and at least one minor soil and is named for the major soil(s). Two general soil associations are found around gravel pits that now form Shadyside Park Lake and Vulcan Lake. They are the Fox-Eel association located on terraces and floodplains and the Brookston-Crosby association found in upland areas. The area adjacent to Killbuck Creek and White River contains the Fox-Eel association with 15% of soils in the North watershed and 32% in the South watershed being Fox soils.

Fox soils consist of deep, well-drained soils underlain by stratified sand and gravel or limy till on flood plains and nearly level to strongly sloping terraces. During dry periods, corn and similar crops are affected by a lack of moisture. Crops respond well to applications of nitrogen and other fertilizer. If Fox soils are not limed, their plow layer is medium acid. Appropriate soil and water conservation practices are required due to rapid runoff, severe erosion, and low available moisture capacity.

Eel soils are moderately well drained soils on bottomlands along streams. These soils are neutral to alkaline, runoff is slow to ponded, internal drainage is medium, and available moisture capacity is high to very high. Eel soils are productive, if floods do not damage crops, but can erode along streambanks when not protected. Corn and soybeans are principal crops. Eel soils also occurred in a small part (1.7%) of the Vulcan Lake watershed.

The rest of the watershed lying to the east and north of the streams is mapped as a Brookston-Crosby soil association. However, the watershed of the North Basin of Shadyside Lake is the only area that is predominately Brookston-Crosby soils with this association at 56% and 12% Miami-Celina soils. Brookston-Crosby soils are light-colored to dark-colored, deep, somewhat to very poorly drained soils of uplands. Crosby soils are low in organic matter and occur in nearly level to slightly undulating areas. Brookston soils are high in organic matter and occupy broad depressional flats, swales with many rounded projections, and narrow drainageways. These soils have high to medium moisture capacity. Brookston soils are well suited to corn and other grains. Crops in Crosby soils respond well to lime and a complete fertilizer but may require tile drainage to ensure good yields due to high spring water tables.

The South Basin watershed contains 29% Miami-Celina soils and only 0.4% Brookston-Crosby soils. Miami-Celina soils are well-drained to moderately well-drained soils on nearly level to steep uplands over till plains along drainageways. These soils are productive with medium to high available moisture capacity and medium to very rapid runoff. The plow layer of Miami soils is medium acid. Crops respond well to applications of lime, organic matter, and a complete fertilizer. Protection from erosion is needed on both soils.

The Vulcan Lake watershed consists of 33% Camden soils. Camden soils are well-drained soils on terraces that occupy nearly level to sloping areas of outwash plains or along valleys of major streams. These soils have medium to high available moisture capacity and medium runoff. The plow layer is medium to strongly acid. Crops respond well to application of nitrogen and other fertilizer. Areas are slightly to moderately susceptible to erosion and can be protected with contour cultivation and a suitable cropping system.

Knowledge of individual soil types in an area is essential for developing appropriate conservation and land use plans. Soil types, acreage, percent of watershed covered by each soil type, and erodibility are listed for the Shadyside Park Lakes (Table 1; Figure 5) and Vulcan Lake (Table 2; Figure 6). Erodibility is a function of: 1) soil texture; 2) length and degree of slope; and 3) presence of erosive forces (e.g., rain or wind).

Table 1. Soil types, acreage, percent of watershed covered, and erodibility in the Shadyside Park Lakes watershed, Madison County, Indiana. Percent slope is given in parentheses behind applicable soil types. Soil types that are considered Highly Erodible Land (HEL) are indicated with an asterisk (*). Moderately eroded soils are indicated as “ME” and “SE” for severely eroded. A “W” indicates wetland soils. Susceptibility to sheet and rill erosion by water is indicated by erosion factor K, which ranges from 0.05 to 0.69, decreasing in susceptibility with higher numbers. Total HEL and wetland soils are listed at the bottom of the table.

				North Basin		South Basin		erodibility
Soil	Description	erosion	wet	acres	%	acres	%	K
Br	Brookston silt loam		W	31.6	1.5	0	0	.28
Bs	Brookston silty clay loam		W	233.3	11.1	0	0	.24
CaA	Camden silt loam (0-2%)			23.5	1.1	0	0	.43
CnA	Celina silt loam (0-2%)			77.7	3.7	0	0	.43
CnB2	Celina silt loam (2-6%)			63.6	3	0.7	0.2	.43
CrA	Crosby silt loam (0-2%)			920.8	43.9	1.3	0.4	.49
CrB2	Crosby silt loam (2-6%)	ME		6.5	0.3	0	0	.49
FoA	Fox silt loam (0-2%)			36.7	1.7	69.7	21	.37
FoB2	Fox silt loam (2-6%)	ME		6.4	0.3	2	0.6	.37

Table 1. Soil types, acreage, percent of watershed covered, and erodibility in the Shadyside Park Lakes watershed, Madison County, Indiana, continued.

				North Basin		South Basin		erodibility
Soil	Description	erosion	wet	acres	%	acres	%	K
FsA	Fox silt loam, till (0-2%)			79.7	3.8	0	0	.49
FsB	Fox Silt loam, till (2-6%)			45	2.1	8	2.4	.49
FsB2	Forx silt loam, till (2-6%)	ME		92.6	4.4	15.3	4.6	.49
FsC	Fox silt loam, till (6-12%)			8	0.4	0	0	.49
*FsC2	Fox silt loam, till (6-12%)	ME		25.5	1.2	11.6	3.5	.49
*FtC3	Fox soils (6-12%)	SE		22.3	1.1	0	0	.20
Gr	Gravel pits			4.8	0.2	5	1.5	---
Kg	Kokomo silty clay loam		W	52.6	2.5	0.7	0.2	.20
Ml	Mahalasville silty clay loam	W	84.5	4	0	0	.20	
MnA	Miami silt loam (0-2%)			6.4	0.3	60.1	18.1	.43
MnB2	Miami silt loam (2-6%)			85.1	4.1	18.6	5.6	.43
*MnC2	Miami silt loam (6-12%)	ME		14.3	0.7	0	0	.43
*MnD2	Miami silt loam (12-18%)	ME		7.2	0.3	0	0	.43
*MpB3	Miami soils (2-6%)	SE		13.1	0.6	0	0	.32
*MpC3	Miami soils (6-12%)	SE		23.1	1.1	11	3.3	.32
*MpD3	Miami soils (12-18%)	SE		0	0	5	1.5	.32
OcA	Ockley silt loam (0-2%)			22.3	1.1	5.6	1.7	.37
OcB	Ockley silt loam (2-6%)			15.1	0.7	18.6	5.6	.37
Sl	Sleeth silt loam			3.2	0.2	21.6	6.5	.32
Sm	Sleeth silt loam, loamy substratum		27	1.3	0	0	.32	
Wc	Washtenaw complex			34.3	1.6	19.2	5.8	.37
Wd	Westland silty clay loam			14.3	0.7	0	0	.28
Ws	Westland silty clay loam		W	0.8	0.1	14.9	4.5	.28
Water				19.7	0.9	43.3	13	---
Total				**2,101**	**100**	**332.2**	**100**	

Total Highly Erodible Land (HEL):

North Basin = 105.5 acres (5% of land acreage)

South Basin = 27.6 acres (9.6% of land acreage)

Total wetland soils:

North Basin = 402.8 acres (19.4% of land acreage)

South Basin = 15.6 acres (5.4% of land acreage)

Figure 5. Soil types for the watershed to Shadyside Park Lake. Definitions for abbreviations are given in Table 1. Redrawn from maps in the Soil Survey of Madison County, Indiana.

Table 2. Soil types, acreage, percent of watershed covered, and erodibility in the Vulcan Lake watershed, Madison County, Indiana. Percent slope is given in parentheses behind applicable soil types. Soil types that are considered Highly Erodible Land (HEL) are indicated with an asterisk (*). Moderately eroded soils are indicated as "ME" and "SE" for severely eroded. A "W" indicates wetland soils. Susceptibility to sheet and rill erosion by water is indicated by erosion factor K, which ranges from 0.05 to 0.69, decreasing in susceptibility with higher numbers. Total HEL and wetland soils are listed at the bottom of the table.

Soil		erosion	wet	acres	%	erodibility K
CaA	Camden silt loam (0-2%)			62.6	20.7	.43
CaB2	Camden silt loam (0-6%)	ME		37.2	12.3	.43
CrA	Crosby silt loam (0-2%)			1.8	0.6	.49
Es	Eel silt loam			5.1	1.7	.43
FoA	Fox silt loam (0-2%)			23.3	7.7	.37
FoB2	Fox silt loam (2-6%)	ME		13	4.3	.37
*FoC2	Fox silt loam (6-12%)	ME		5.4	1.8	.37
FsA	Fox silt loam, till (0-2%)			6.3	2.1	.49
FsB2	Fox silt loam, till (2-6%)	ME		19	6.3	.49
*FsC2	Fox silt loam, till (6-12%)	ME		15.4	5.1	.49
*FtC3	Fox soils (6-12%)	SE		13	4.3	.20
Gn	Genesee silt loam			6	2	.43
Gr	Gravel pits			34.1	11.3	---
*MpC3	Miami soils (6-12%)	SE		13	4.3	.32
*MpD3	Miami soils (12-18%)	SE		6	2	.32
Rs	Ross silt loam			16	5.3	.37
So	Sloan silt loam			4.5	1.5	.24
Ws	Westland silty clay loam, mod deep	W	5.7	1.9	.28	
Water				14.4	4.8	---
Total				**301.8**	**100**	

Total Highly Erodible Land (HEL):

Vulcan Lake = 52.8 acres (18.4% of land acreage)

Total wetland soils:

Vulcan Lake = 5.7 acres (2.0% of land acreage)

Figure 6. Soil types for the watershed to Vulcan Lake. Definitions for abbreviations are given in Table 2. Redrawn from maps in the Soil Survey of Madison County, Indiana.

3.2.1 CURRENT LAND USE

The watersheds of Shadyside Park and Vulcan Lakes have undergone rapid and continuous suburban development over the past 50 years as shown in a time series of maps (Figures 7-8). Due to the diversity of data formats and limitations on aerial measurements, the following land use information should be viewed as an approximation. In 1939, the majority of all three watersheds was used for agriculture, which had changed by 1997 to none in Vulcan Lake, 9 acres (2.7% of area) in the South Basin, and 634 acres (30%) in the North Basin (Table 3; Figure 9). Over the same time period, development has slowed in the North basin watershed, steadily increased in the South Basin, and increased most dramatically since 1981 in the Vulcan Lake watershed. Population density is high around Vulcan Lake and moderate but increasing around Shadyside Park (Figure 10; 1990 U.S. Census Bureau data).

Material mining has increased over the nine years from 1988 to 1997 in the Shadylake Basins from none to 12% in the North and to 29% in the South basin. Sand and gravel mining is no longer conducted in the Vulcan Lake watershed (down from a peak of 37% in 1981). Mining was inversely related to cropland area in all three watersheds. When mining ceased in the Vulcan Lake watershed, previously mined areas were converted to parkland with a consequent dramatic increase in forested area and open space. Ironically, mining activity probably protected these areas from development as a large private landholding through periods of rapid development.

3.3 NATURAL AREAS AND BIODIVERSITY

Rapid development emphasizes the importance of the Anderson Park areas for conservation of threatened and endangered species in this area. Several endangered, threatened and rare species have been documented from Madison County in the region around the Anderson City Lakes watersheds, particularly on state-owned properties (Table 4). However, viable wildlife habitat is somewhat limited in the Shadyside Park watershed. Protected areas consist mainly of parkland, remaining cropland to the east of Highway 9, and an area currently under earthmoving activities for material mining. The 1961 aerial photo indicated a significant number and size of forested tracts that have since been converted to cropland. Between the 1980s and 1990s, some forest was apparently recovering in upland areas. In the Vulcan Lake watershed, areas available for protection or restoration of wildlife habitat are restricted to the abandoned gravel mining property.

3.4 EROSION CONTROL

Soil erosion can be very costly for land and water management in rural and urban areas. Erosion diminishes productivity and increases runoff by resulting in reduction of infiltration, loss of basic plant nutrients, and degradation of soil structure. Conventional plow-disk farming of corn in Indiana induces soil loss of 19 tons per acre per year (47 tons/ha). As a result, corn yields on severely eroded soil have been shown to decrease by

Figure 7. Time series of development around Shadyside Park Lake, Madison County, Indiana, in 1939, 1956, 1961, 1981/88, and 1997. Redrawn from aerial photographs at the Indiana State Archives, Commission on Public Records. The 1997 information is drawn from a field survey. (o = open space; c = cropland; f = forest; s = subdivision with dense houses; m = mining; D = number of duplexes or other buildings; H = number of houses)

Figure 7. Time series of development around Shadyside Park Lake, Madison County, Indiana, continued.

Figure 7. Time series of development around Shadyside Park Lake, Madison County, Indiana, continued.

Figure 8. Time series of development around Vulcan Lake, Madison County, Indiana, in 1939, 1956, 1961, 1981, and 1997. Redrawn from aerial photographs at the Indiana State Archives, Commission on Public Records. The 1997 information is drawn from a field survey. (o = open space; c = cropland; f = forest; s = subdivision with dense houses; m = mining; B = number of buildings; H = number of houses)

Figure 8. Time series of development around Vulcan Lake, Madison County, Indiana, continued.

Figure 8. Time series of development around Vulcan Lake, Madison County, Indiana, continued.

Table 3. Land use in the Shadyside Park Lakes watershed in 1939, 1961, 1980s, and 1997. Land use is given to the nearest acre. (Topographic maps representing two quadrangles that include watersheds of the north and south basins were updated in 1981 and 1988.)

North Basin

Land use	1939 (acres)	1961 (acres)	1981/88 (acres)	1998 (acres)
water	0	20	20	20
forest	4	371	77	111
open	0	43	105	247
mining	0	0	17	95
crops	2077	340	934	634
residential	19	259	845	890
commercial	0	0	104	104

South Basin

Land use	1939 (acres)	1961 (acres)	1981/88 (acres)	1997 (acres)
water	0	13	43	43
forest	35	14	36	46
open	0	1	63	36
mining	0	0	0	98
crops	300	39	109	9
residential	0	16	82	99
commercial	0	<1	1	1

Vulcan Lake

Land use	1939 (acres)	1961 (acres)	1981 (acres)	1997 (acres)
water	0	14	14	14
forest	90	86	25	31
open	23	81	97	9
mining	189	70	34	0
crops	0	42	110	0
residential	0	6	18	245
commercial	0	3	4	4

Figure 9. Trends in land use distribution in the Shadyside Park and Vulcan Lake watersheds, Madison County, Indiana, in 1939, 1961, 1981, and 1997. Land use is given as percent of total watershed area. Land use categories are: water, forest, open, crops, mining, residential, commercial.

Figure 9. Trends in land use distribution in the Shadyside Park and Vulcan Lake watersheds, Madison County, Indiana, continued.

Figure 10. Population density around Shadyside Park Lake and Vulcan Lake in Anderson, Madison County, Indiana based on 1990 US Census Bureau data. (black = 5,415 persons / sq mi; dark green = 2,430-5,415 persons / sq mi; medium green = 551-2,430 persons / sq mi; light green = 49-551 persons / sq mi; white = no data)

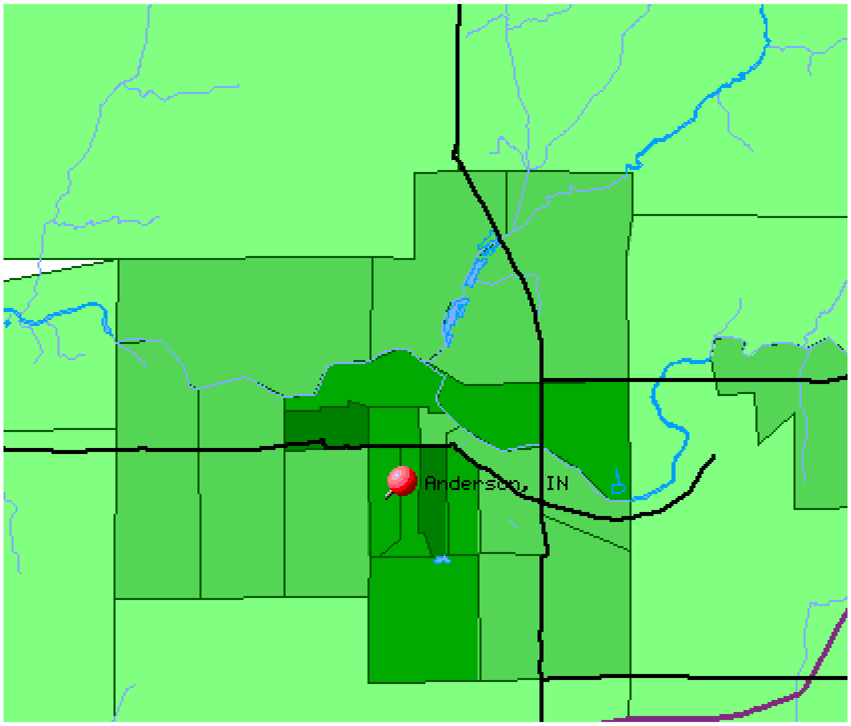


Table 4. Endangered, threatened and rare species that have been documented from Madison County. (Classification in order from most rare to more common - Federally listed: LE = endangered. State listed: SX = extirpated, SE = endangered, ST = threatened, SR = rare, SSC = special concern, WL = watch list, SG = significant; Indiana Heritage Trust Database, November 21, 1997).

Common name	Species name	Status	Date
Killbuck Creek at White River:			
Mussel: Clubshell	*Pluerobema clava*	SE / LE	1989
Mussel: Lilliput	*Toxolasma parvus*	SE	1989
Mounds Fen Nature Preserve (DNR Parks & Reservoirs):			
High quality wetland	Fen	SG	1990
Plant: Tufted hairgrass	*Deschampsia cespitosa*	SR	1990
Plant: Butternut	*Juglans cinerea*	WL	1982
Plant: Meadow spike-moss	*Selaginella apoda*	SE	1992
Plant: Wide-leaved ladies'tresses	*Spiranthes lucida*	SR	1992
Mounds State Park (DNR Parks & Reservoirs):			
High quality community	Mesic upland forest	SG	1990
Plant: Butternut	*Juglans cinerea*	WL	1982

up to 24 percent on Illinois and Indiana farms (Pimentel and others 1995). Erosion rates of 6.9 tons per acre per year (17 tons/ha/yr) could cost farmers $79 per acre ($196/ha/yr) to replace the benefits of water and nutrients. For every $1 invested in soil conservation, an estimated $5.24 in replacement costs would be saved.

Tillage practices in Madison County protect most of the cropland from losses in productivity due to erosion. A recent survey of tillage practices across Indiana showed that 48 percent of the cropland in the Madison County portion of the West Fork White River basin was in conservation tillage in 1996, representing an increase of 42 percent since 1990 (Hill et al. 1996). Average erosion rates in 1996 were 2.7 tons per acre (lower than the state average of 3.0 tons per acre). Approximately 80 percent of the 1996 cropland was eroding at or below "T," or the tolerable level to replenish most of the lost soil, which was better than average for all counties in the river basin (75 percent). Only 3 percent of cropland in the county was eroding at greater than 3 tons per acre above T.

One of the long-term costs of erosion is deteriorating water quality. About 60 percent of the soil lost from U.S. cropland each year is deposited in streams and rivers (USDA, 1989). This sediment clogs waterways, accelerates aging in lakes, and reduces the storage capacity of reservoirs. Dredging to remove silt and restore function to these systems costs over $520 million annually in the U.S. (Clark 1985).

Much of the fragile soils in the Shadyside Park and Vulcan Lakes watersheds border waterways or steep slopes. A relatively small portion of these watersheds consist of highly erodible land (North Basin: 105.5 acres or 5% of the land acreage; South Basin: 27.6 acres or 9.6% of the land acreage; Vulcan Lake: 52.8 acres or 18.4% of the land acreage; Figures 11-12). The location of these soils may provide ready transport to waterways where damage may be severe with a relatively small amount of soil. In addition, it is important to note that soils defined as less susceptible to erosion *will* erode if left unprotected.

Bands of erodible soils border drainageways leading into Shady Run and the North Basin. One stretch of Miami silt loam and Fox silt loam runs parallel with the west side of Highway 9. The band starts at the intersection of Nursery Road and Lindbergh Road (C.R. 100N) and continues north through a residential area and across the main facility of Irving Materials Incorporated (IMI), a sand and gravel mining company. Bands of Fox silt loam and Fox soils with 6-12 percent slopes and classification of moderately and severely eroded soils underlay the relatively new Cross Lakes Luxury Apartments. The older residential area immediately to the east lies over similar soils. The older subdivision to the south along Hwy 9 is ringed with Fox silt loam over till with 6-12 percent slopes, moderately eroded. The entire headwaters of Shady Run paralleling Hwy 9 to the east consists of Miami silt loam and Miami soils with 6-12 percent slopes, moderate to severely eroded.

One long broken band of erodible soils crosses headwater areas of drainageways to the South Basin. Severely eroded Miami soils lie along a slope extending across a grassy open area from the west and north edges of the Maplewood Cemetery to a new subdivision at the south side of Lindbergh Road (C.R. 100N). A band of Fox silt loam and Miami soils continues in a northeast direction across an area undergoing earthmoving activities and bordering a corn field to the north of Lindbergh Road.

A wide band of erodible soils separates residential areas on the north of the Vulcan Lake watershed from proposed park areas. This band consists of Fox silt loam over till and Fox soils with 6-12 percent slopes, moderately to severely eroded, and Miami soils with 6-18 percent slopes, severely eroded. These fragile soils encompass the headwaters and border the northern slopes of all drainageways leading into the Vulcan Lake area. Most of the area to the southwest of the water tower is forested and appears stable. However, the soils extend into the subdivision at the southwest corner of the intersection at Rangeline Road and 10th Street.

Regulations that implement the Indiana Flood Control Act (I.C. 14-28) require a permit for construction in a floodway on a stream that has a drainage area of one (1) or more square miles (310 IAC 6-1-2). The permit requirement applies to Killbuck Creek. As of March 31, 1999, the IDNR Division of Water permit database showed 24 floodway

Figure 11. Highly erodible land (shaded areas) around Shadyside Park Lake, based on USDA Natural Resources Conservation Service definitions. Redrawn from maps in the Soil Survey of Madison County, Indiana.

Figure 12. Highly erodible land (shaded areas) around Vulcan Lake, based on USDA Natural Resources Conservation Service definitions. Redrawn from maps in the Soil Survey of Madison County, Indiana.

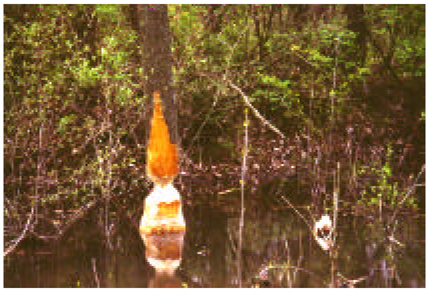
permit applications for Killbuck Creek and none on Shady Run. The applications included: five permits for outfalls (stormwater or treated effluent); eight permits for utility crossings (sewer mains and natural gas pipelines); two for log jam removal; two bridges; and the remainder for construction of driveways, residences, a restored wetland and pedestrian path, and a retail shopping center with paved parking lot.

3.5 WILDLIFE HABITAT, WETLANDS AND DEVELOPMENT

Hydric soils indicate where wetlands were located or could be restored (Figures 13-14). Four soil types in these watersheds (Brookston, Kokomo, Mahalasville, and Westland) consist of humic gley soils, which form under forested wetland conditions. These soils make up 19% (403 acres) of the North Basin watershed, mostly found along drainageways and in forested areas of the upper watershed and along lower Shady Run. Much less (5%) of the South Basin watershed consists of wetland soils, all of which is located immediately east of the lower half of the South Basin. Wetland soils are found in only 2% of the Vulcan Lake watershed in an isolated forest tract just northwest of the lake and adjacent open area.

Wetland restoration or enhancement requires an appropriate combination of soil types, topography, and coordination with existing or potential land uses. Wetlands located near waterways have an increased value for filtering and wildlife habitat. Wetland soils that could provide filtering buffers for waterways in the Shadyside Park area include: 1) a broad area curving along a drainage way leading into lower Shady Run from the intersection of Cross Road and Highway 9; 2) scattered drainage swales in the upper watershed of the North Basin; and 3) a 15 acre area within the Park adjacent to the lower half of the South Basin. The only significant area of the Vulcan Lake watershed with wetland soils is relatively intact as an isolated forest patch of about 5.7 acres.

Further information on species selection for woodland management, windbreaks, development of recreational facilities, habitat potential for wildlife, building sites, suitability for sanitary facilities, and physical, chemical, and engineering properties of individual soil types are available in the Madison County Soil Survey. Soils may vary at particular sites from the broader resolution offered by the soil survey. Therefore, soils must be sampled at specific sites to determine the appropriate use for that area.



Evidence of beaver along the northwest shore of Vulcan Lake.

Figure 13. Hydric or wetland soils (shaded areas) around Shadyside Park Lake, Madison County, Indiana, based on USDA Natural Resources Conservation Service definitions. Redrawn from maps in the Soil Survey of Madison County, Indiana.

Figure 14. Hydric or wetland soils (shaded areas) around Vulcan Lake, Madison County, Indiana, based on USDA Natural Resources Conservation Service definitions. Redrawn from maps in the Soil Survey of Madison County, Indiana.

4.0 LAKE ASSESSMENT

Lakes are complex ecosystems in which physical, chemical, and biological characteristics function interdependently. Large-scale factors, such as climate and geology, set the stage within which individual lake characteristics develop. Lakes in northern Indiana tend to be highly productive glacially-formed hardwater lakes surrounded by forested wetlands. These lakes change naturally over hundreds or thousands of years. Some physical and chemical factors, like temperature and light, exhibit a fairly stable range that determines the types of organisms that can survive in the system. Other physical and chemical factors, like dissolved oxygen, vary significantly over seasons and years in response to activity and growth of plants and animals.

The lakes addressed in this study have the same geologic, climatic, and biological setting as natural lakes, but also have additional unique characteristics derived from their origin as sand and gravel mining pits. Abandoned mining pits do not have a naturally formed watershed, are often located near a large river and may exchange flood water with the river, and are generally influenced significantly by groundwater flow and characteristics. These factors are very important in describing the function and potential of these Anderson Park lakes. Specific physical, chemical, and biological characteristics of the Shadyside Park and Vulcan Lakes are described below.

4.1 STRATIFICATION

With the exception of very shallow lakes, most lakes in northern Indiana will stratify so that warmer water remains near the surface of the lake and water at the bottom is colder. Due to differences in temperature and density during the summer, warmer water at the surface "floats" as an upper layer (epilimnion) and does not mix with denser, colder water at the bottom (hypolimnion). Between these two layers is the metalimnion, where chemical conditions and temperature are rapidly changing from surface to bottom conditions. In winter, water temperatures and chemistry are similar from top to bottom.

As a result, chemical characteristics of surface and bottom water may differ dramatically, such that few organisms can live in deeper parts of the lake in summer. Both basins of Shadyside Park Lake exhibited thermal and chemical stratification during late summer sampling on August 6, 1996. While the full range of stratification was visible in the deeper South Basin, the shallower North Basin had only a few feet of distinctly stratified water (Figure 15). Vulcan Lake was too shallow to show stratification.

4.1.1 OXYGEN AND TEMPERATURE

In some lakes, supersaturation of oxygen indicates high productivity of algae and other aquatic plants during the day and may reach 150% or more in surface waters of highly eutrophic lakes. At night the reverse process may take place, causing an equivalent amount of oxygen to be removed from the water by respiring plants. This

Figure 15. Temperature in the North and South basins of Shadyside Park Lake, Madison County, Indiana, in 1975, 1976, 1977, 1979, 1991, 1994, and 1996. Temperature is given in degrees Fahrenheit and depth is given in feet from the surface.

pattern can lead to massive fish kills through suffocation in highly productive lakes or may at least severely limit survival of sensitive fish species.

Oxygen saturation and pH levels were very high at the surface in both basins of Shadyside Park Lake during 1996, suggesting extreme primary productivity. Levels of oxygen were supersaturated from 100% to 180% from the surface to a depth of about four feet in all lakes with a second peak at five to eight feet in the South Basin and Vulcan Lake (Tables 5-7). Due to oxygen limitation (< 4 mg/l) in both basins at Shadyside Park, only the upper 10 feet of water can support gamefish during the summer.

Table 5. Stratification of the South Basin of Shadyside Park Lake, Madison County, Indiana in late summer, August 6, 1996, at the deepest part of the lake. Parameters given are depth (ft), dissolved oxygen (mg/l), temperature (°F), and percent saturation for dissolved oxygen at depths of every foot from surface to bottom.

depth (ft)	**temp (F)**	**D.O. (mg/l)**	**saturation (%)**
0	81	13	160
1	82	13.2	162
2	82	13.5	165
3	81	13.4	164
4	80	13.9	172
5	80	15	182
6	79	14.3	173
7	78	14.2	171
8	78	13.3	160
9	77	9.9	119
10	76	5.6	67
11	75	2.6	30
12	74	1.3	15
13	73	0.3	3
14	72	0.8	9
15	69	0.5	5
16	64	0.4	4
17	60	0.2	2
18	58	0.1	1
19	56	0.1	0
20	55	0.1	0
21	55	0.1	0
22	53	0	0
23	53	0	0

Table 6. Stratification of the North Basin of Shadyside Park Lake, Madison County, Indiana in late summer, August 6, 1996, at the deepest part of the lake. Parameters given are depth (ft), dissolved oxygen (mg/l), temperature (^oF), and percent saturation for dissolved oxygen at depths of every foot from surface to bottom.

depth (ft)	**temp** (F)	**D.O.** (mg/l)	**saturation** (%)
0	80	15.0	181
1	80	13.6	167
2	80	14.2	173
3	80	13.8	170
4	79	13.3	162
5	78	9.5	114
6	77	7.9	93
7	75	6.2	72
8	76	4.6	55
9	75	4.3	52
10	74	3.5	41
11	74	3.3	38
12	73	1.7	19
13	72	1.3	14
14	72	0.3	5

Table 7. Stratification of Vulcan Lake, Madison County, Indiana in late summer, August 6, 1996, at the deepest part of the lake. Parameters given are depth (ft), dissolved oxygen (mg/l), temperature (^oF), and percent saturation for dissolved oxygen at depths of every foot from surface to bottom.

depth (ft)	**temp** (F)	**D.O.** (mg/l)	**saturation** (%)
0	80	11.0	135
1	79	11.3	140
2	79	12.3	152
3	78	11.5	139
4	79	10.3	127
5	77	9.6	113
6	76	10.8	128
7	75	10.8	127
8	74	9.3	107

9	76	7.9	93

Collection of black sediments that smelled of hydrogen sulfide in 1991 (IDNR Fisheries Report) and 1996 indicated that the deeper South Basin is probably permanently anaerobic (without oxygen) at the bottom. Black sediments result from the formation of ferrous sulfide in waters without oxygen. Sulfate reducing bacteria also create hydrogen sulfide in anoxic water at the bottom of lakes. Hydrogen sulfide is poisonous to most other animals because it inactivates the enzyme cytochrome oxidase, which is necessary for breathing (Cole, 1983). Several species of sulfate reducing bacteria use sulfur instead of oxygen to sustain life. These bacteria lack the enzyme catalase and are not susceptible to destruction by hydrogen sulfide.

High levels of hydrogen sulfide may result from natural or human-induced circumstances. The level of hydrogen sulfide in lakes formed by gravel mining may be naturally high due to the larger influence of groundwater in their water chemistry. Water sample data from nine wells around Anderson show the presence of iron and sulfate in the groundwater (IDNR Division of Water files; Table 8). Sulfate levels were relatively low (<100 ppm) and natural iron levels were relatively high (>1.0 ppm) in groundwater in Madison County (Clark, 1980). Pollution from human activity in lake watersheds, contributions from some types of industry, and decomposition of organic matter elevate the amount of organic matter as a source of sulfate (Cole, 1983).

The low pH and low oxygen at the bottom of the lake results in chemical reactions that cause the formation of hydrogen sulfide and ferrous sulfide from the available groundwater sources of these chemicals. Anoxic sediments rich in organic matter release hydrogen sulfide. The sulfide ion from hydrogen sulfide precipitates ferrous sulfide, which is a very insoluble combination of iron and sulfur that gives a black color to sediments.

Table 8. Groundwater chemistry related to iron and sulfur from nine wells around Anderson, Indiana (IDNR Division of Water files). All data are given in ppm.

ref. No.	UTMN	UTME	depth	pH	hardness	iron	alkalinity	sulfate	conductivity
85763	4434460	620670	71	7.21	326	2.1	336	14	481
21868	4441995	623470	45	7.24	370	0.9	287	76	592
85685	4449920	611390	120	7.21	323	3.3	349	0	443
85877	4450050	619030	71	7.33	368	1.4	318	50	512
85872	4434050	611795	112	7.43	272	0.6	315	0	423
82184	4433120	625660	66	6.78	500	0.3	316	59	860
82188	4437630	626270	96	7.16	377	2.2	273	91	503
142321	4443875	617910	43	6.3	456	2.3	292	55	593
82193	4444325	622950	109	6.59	360	1.8	358	2	464
	Groundwater	average =	81.4	7.0	372.4	1.7	316.0	38.6	541.2
		Lake average =		8.1	---	---	236		---
532									

Oxygen data for Shadyside Park Lake over the past 20 years suggested that the lake has been productive, but that water quality has also decreased. Data from the 1970s indicated that supersaturation has been a chronic problem in Shadyside Park Lake (Figure 16), but that oxygen was also available to a much deeper level (nearly 20 ft) in the 1970s (Figure 17). Oxygen was high to the bottom (9 ft) of Vulcan Lake. No data were available for comparison to other years in Vulcan Lake. These lakes tend to stratify more strongly in wet years (e.g., 1975, 1979) than in dry years (e.g., 1976, 1977).

4.1.2 CHEMISTRY

The level of pH in lakes is controlled by a number of factors. Soil types in gravel pits tend to be high in limestone and have a more basic and well buffered pH. As plants produce oxygen in water, the removal of carbon dioxide is also associated with more basic pH. Respiration and decay of plant and animal materials reduces the pH to a more acidic level. For these reasons, the pH in eutrophic lakes tends to be basic at the surface and acidic at the bottom. The pH levels in all three lakes in the Anderson Parks were typical of productive Indiana lakes, ranging from 7 at the bottom to 9 at the surface (Table 9; Figure 18). Lower and more variable surface pH levels in the South Basin during the 1990s suggested reduced plant productivity in recent years. The deeper basin also most likely has a large groundwater component influencing water chemistry at the bottom. Groundwater in Anderson wells had an average pH of 7. Phosphorus and some toxins, such as heavy metals, are released into the water when pH levels drop and water becomes more acidic. Ferrous sulfide precipitates to form black colored sediments when pH drops.

Table 9. Level of pH in Shadyside Park Lake and Vulcan Lake, Madison County, Indiana in summer from 1975 to 1996.

	1975	1976	1977	1979	1991	1994	1996
South Basin (surface)	9	9	9	9.1	7.6	8	8.9
South Basin (bottom)	7.5	7.5	7.5	7.5	7	8	7.5
North Basin (surface)	---	---	---	---	8.2	8.5	8.6
North Basin (bottom)	---	---	---	---	7.9	7.5	7.7
Vulcan Lake (surface)	---	---	---	---	---	---	8.6
Vulcan Lake (bottom)	---	---	---	---	---	---	7.8

Alkalinity is a measure of the buffering capability of lakes. Alkalinity levels above 50 mg/l in hardwater lakes buffer pH and reduce negative effects of acidic pH and associated chemical reactions. Seasonal and daily shifts in pH are generally less dramatic in northern Indiana lakes, because carbonates from erosion of limestone and other minerals from the soil can buffer pH changes. Other chemicals, such as borates, phosphates, silicates, and other bases also affect alkalinity. In polluted lakes, organic anions may become a part of total alkalinity.

Figure 16. Oxygen saturation in the North and South basins of Shadyside Park Lake, Madison County, Indiana, in 1975, 1976, 1977, 1979, 1991, 1994, and 1996. Saturation is given in percent and depth is given in feet from the surface.

Figure 17. Dissolved oxygen levels in the North and South basins of Shadyside Park Lake, Madison County, Indiana, in 1975, 1979, 1991, 1994, and 1996. Dissolved oxygen (DO) is given in milligrams per liter and depth is given in feet from the surface. Shaded areas indicate the depth at which most life could no longer be sustained (4 mg/l dissolved oxygen) in average rainfall years during the 1990s (upper shading) and the 1970s.

Figure 18. Level of pH at the surface and bottom of the North and South basins of Shadyside Park Lake in 1975, 1976, 1977, 1979, 1991, 1994, and 1996 and at Vulcan Lake, Madison County, Indiana, in 1996.

Plant productivity can influence lake alkalinity. Daytime photosynthesis of plants removes carbon dioxide (CO_2) from the water and causes calcium carbonate ($CaCO_3$) to precipitate, lowering total alkalinity. This effect is exacerbated in warmer water. Precipitates of calcium carbonate fall to the bottom of the lake, where they are reabsorbed into the water and increase the alkalinity in deeper waters. Alkalinity becomes more even throughout the lake at turnover and through the winter.

The high levels of nutrients in the groundwater that influence chemistry of the Anderson Park lakes probably drive very high baseline productivity, aside from additional influences from human activity. Elements such as calcium, magnesium, sodium, potassium, sulfur, chlorine, iron, and other minor metals constitute nutrients that are required for growth of plants and animals but are usually available only in small quantities. The availability of these nutrients due to geological sources, human pollutants, and other aspects of water chemistry will determine the potential productivity of a lake. Hardness for Anderson wells ranged from 272 to 500 mg/l, which is typical to somewhat high for groundwater in limestone areas and indicates the presence of a number of elemental nutrients. Groundwater in wells around Anderson showed very high levels of calcium, magnesium, chloride, high levels of sulfide, alkalinity, and sodium, and low levels of potassium (Table 10). These chemicals may be derived from gypsum and pyrites and increased levels may occur through disturbance from mining activity. According to Moss (1972), levels found in the Anderson groundwater would correspond with very eutrophic (productive) water that supports mostly bluegreen algae (*Aphanizomenon* and *Microcystis*) and the diatom *Fragilaria* at the expense of desmids and other diatoms that are more indicative of oligotrophic waters.

Table 10. Groundwater chemistry related to alkalinity and major ions from nine wells around Anderson, Indiana (IDNR Division of Water files). All data are given in ppm. Well location coordinates are given in Table 8.

ref. No.	calcium	magnesium	sodium	potassium	cloride	sulfate	alkalinity
85763	84	28	5	0.5	2	14	336
21868	94	33	19	0.9	45	76	287
85685	82	29	6	0.6	2	0	349
85877	92	33	6	1.1	13	50	318
85872	58	31	14	1	1	0	315
82184	139	37	54	2	167	59	316
82188	97	33	2	1	12	91	273
142321	117	40	6	1	83	55	292
82193	93	31	6	1	11	2	358
average	95.1	32.8	13.1	1.0	37.3	38.6	316.0

High conductivity and TDS suggested significant contributions of silt and other soluble materials from runoff in the watershed to the lakes, particularly from Shady Run into the North Basin. Dissolved substances, alkalinity, and conductivity in Shadyside Park Lake may indicate an increase in pollution and plant productivity over the past 20 years (Table 11, Figure 19). Average alkalinity ranged from a low of 168-209 mg/l in the North Basin during the 1970s to a high of 290-453 mg/l in both basins by 1994. Except for one year in each basin, alkalinity was consistently lower at the surface than at the bottom. These figures are consistent with high plant productivity at the surface of the lake, as described above. Eutrophic lakes commonly contain greater than 185 mg/l TDS (Cole 1983). In 1991, TDS averaged 200 in the South Basin and 260 in the North Basin, which is consistent with a eutrophic condition. Conductivity in Shadyside Park Lake was within the average range of 588±121SD umhos/cm for Indiana streams (data from IDEM 1991). During the 1990s, alkalinity, conductivity, and total dissolved solids were all higher in the North Basin than in the South Basin.

Table 11. Dissolved substances in Shadyside Park Lake and Vulcan Lake, Madison County, Indiana in summer from 1975 to 1991, as measured by alkalinity, conductivity, and total dissolved solids (TDS) in mg/L.

	alkalinity						conductivity		TDS
	1975	1976	1977	1979	1991	1994	1991	1994	1991
South surface	231	130	130	171	188	290	460	412	190
South bottom	187	205	205	205	254	---	611	410	210
North surface	---	---	---	---	222	393	565	517	240
North bottom	---	---	---	---	154	513	706	571	280
Average (South)	209	168	168	188	221	290	536	411	200
Average (North)	---	---	---	---	188	453	636	544	260

4.2 LIGHT AND PLANKTON

Phytoplankton are microscopic plants that function as primary producers of food and oxygen in lake ecosystems. As with other plants, phytoplankton require light and nutrients to thrive. Transparency and light penetration in the water regulate the type and location of phytoplankton in the lake. In turn, phytoplankton can affect light penetration and dissolved oxygen levels in eutrophic lakes.

Most of the energy produced by phytoplankton is transferred through the food web via consumption of phytoplankton by small zooplankton (microscopic “animals”), which are eaten in turn by larger zooplankton or young fish. Only a few species of adult fish in temperate lakes feed directly on phytoplankton. Populations of phytoplankton, zooplankton, and young fish are intimately connected, depending on population size and feeding rate of predators and prey in the food web. Expansion of one group may cause a corresponding increase in its predators and decrease in its prey.

Figure 19. Total dissolved solids (TDS), alkalinity, and conductivity at the surface and bottom of the North and South basins of Shadyside Park Lake, Madison County, Indiana, in 1975, 1976, 1977, 1979, 1991, 1994, and 1996. Total dissolved solids (TDS) is given in milligrams per liter, conductivity is in umhos per centimeter, and alkalinity is in parts per million.

4.2.1 LIGHT AND WATER CLARITY

Water clarity in Shadyside Park Lake has fluctuated but showed no obvious trend towards degradation since the mid-1970s. A Secchi disk, which is a round plate on a rope painted in a contrasting black and white pattern, is a simple but effective device for measuring water clarity in lakes. The disk is lowered into the water until no longer visible and that depth is noted. Secchi depths were not statistically different between the basins or between the late 1970s and early 1990s (Table 12; Figure 20). Both basins registered unusually clear readings during 1976, especially in the North Basin, which receives direct drainage from Shady Run. The majority of Indiana lakes have a Secchi depth greater than 5 ft (IDEM, 1986). Therefore, water clarity in Shadyside Park Lake would need to improve by up to 30 percent to achieve average clarity. In contrast, water clarity in Vulcan Lake was better than the Indiana average and over twice as deep as in Shadyside Park Lake for the single year of available data (1996).

Table 12. Water clarity as indicated by Secchi depth in Shadyside Park Lake and Vulcan Lake, Madison County, Indiana in summer from 1975 to 1996 (in feet). Statistical computations do not include the outlier readings in 1976. (std dev = standard deviation)

	1975	1976	1977	1979	1991	1994	1996	average	std dev
South Basin	-4.0	-8.0	-4.5	-2.8	-4.2	-6.0	-2.5	-3.9	1.4
North Basin	-2.3	-14.0		-3.8	-3.6	-4.5	-3.5	-3.5	0.8
Vulcan Lake							-6.8		

Water clarity may be directly affected by suspended silt, growth of microscopic algae or dissolved substances that color the water. Seasonal changes in water clarity would indicate the potential cause of lower clarity. The most likely significant factors contributing to reduced water clarity are: 1) sedimentation in runoff after rains, especially in spring; or 2) an increase in algae populations in response to mixing of nutrients from the lake bed at turnover.

The greatly improved water clarity in one drier year (1976) in the North Basin suggested that sedimentation from Shady Run may have been a primary contributor to reduced visibility in years with more rain. The strong relationship in both basins between monthly precipitation and water clarity from 1975 to 1996 suggests that watershed land use significantly affects lake water quality (South Basin: Pearson's $r = 0.39$, $n=7$; North Basin: $r = 0.42$, $n=6$; Table 13; Figure 21). Because there is no historical record of water quality in Vulcan Lake, no conclusions could be drawn regarding relationship to precipitation based on available data.

Figure 20. Water clarity (Secchi depth) in the North and South basins of Shadyside Park Lake, Madison County, Indiana, in 1975, 1976, 1977, 1979, 1991, 1994, and 1996 and in Vulcan Lake in 1996. Secchi depth is given in feet.

Figure 21. Relationship between water clarity (Secchi depth) and annual precipitation in the North and South basins of Shadyside Park Lake in 1975, 1976, 1977, 1979, 1991, 1994, and 1996. Secchi depth is given in feet. Annual precipitation is given in inches based on data measured at the Anderson Sewage Treatment Plant as reported by the NOAA National Climatic Data Center. (South Basin: Pearson's $r = 0.39$, $n = 7$; North Basin: Pearson's $r = 0.42$, $n = 6$)

Table 13. Relationship between annual precipitation at the Anderson Sewage Treatment Plant and water clarity in the Shadyside Park Lakes from 1975 to 1996.

Year	annual precipitation (inches)	water clarity: South (feet)	North (feet)
1975	44.68	4	2.3
1976	32.93	8	14
1977	25.7	4.5	--
1979	41.49	2.8	3.8
1991	31.56	4.2	3.6
1994	32.04	6	4.5
1996	35.96	2.5	3.5

4.2.2 PHYTOPLANKTON

Phosphorus generally acts as the limiting nutrient in fresh water ecosystems. As discussed in detail below, bottom sediments in Shadyside Park and Vulcan Lakes contained high levels of phosphorus. Recycling and availability of phosphorus generally increase in the lake water column towards early fall, as lake water begins to turn over and unlock high levels of phosphorus from the bottom sediments. As nutrients become more available, nuisance algal blooms can occur. Populations of microscopic "plants" (phytoplankton) generally increase with warming temperatures and longer daylight hours into late June and early July, then begin to decrease as herbivorous zooplankton begin feeding on the microscopic plants.

The planktonic algae community in Shadyside Park Lake and Vulcan Lake was adequately balanced between beneficial forms and groups that could potentially create a nuisance (Table 14; Figure 22). Beneficial green algae was very prevalent in the upper waters of Shadyside Park Lake and a combination of green algae and diatoms were abundant in Vulcan Lake, indicating a relatively healthy lake community with food sources for larval fish and other small animals. Bluegreen phytoplankton can be a nuisance in lakes, as described below. However, this problem group constituted only a small portion (25%) of the overall planktonic community in both lakes. The group was represented by *Anabaena* and *Microcystis* in Shadyside Park and *Microcystis* and *Oscillatoria* in Vulcan Lake. More detailed information about the species may reflect water quality and seasonal conditions in the lakes.

Table 14. Plankton in Shadyside Park Lake and Vulcan Lake, Madison County, Indiana in summer, August 6, 1996. (E = epilimnion samples; M = metalimnion samples)

	Vulcan Lake				Shadyside Park Lake			
	E (#/L)	E & M (#/L)	E %	E & M %	E (#/L)	E & M (#/L)	E %	E & M %
Cyanophyta (bluegreen algae)			**46.4**	**24.5**			**15.7**	**24.8**
Anabaena	0	0			39	530		
Anacystis	26	0			0	20		
Microcystis	311	826			0	163		
Oscillatoria	0	321			19	0		
Chlorophyta (green algae)			**46.4**	**32.8**			**79.1**	**73.8**
Chlorococcum	0	0			214	1998		
Closterium	0	115			0	0		
Hydrodictyon	0	0			0	20		
Rhizoclonium	52	23			0	0		
Scenedesmus	0	23			0	0		
Spirogyra	259	1284			78	102		
Volvox	26	92			0	0		
Pyrrhophyta (dinoflagellates)			**3.6**	**0.5**			**0.1**	**0.7**
Exuviella	26	0			0	0		
Gonyolax	0	23			0	20		
Chrysophyta (diatoms)			**3.6**	**42.2**			**5.1**	**0.7**
Asterionella	26	46			0	0		
Fragilaria	0	138			0	0		
Navicula	0	138			0	0		
Synedra	0	1628			19	20		
Synura	0	23			0	0		
Zooplankton			**20**	**13.2**			**13.4**	**4.1**
Copepoda	26	92			19	61		
Cladocera	129	413			19	41		
Rotifera	26	206			19	20		
TOTAL	**726**	**4680**			**369**	**2873**		

Green algae provide a preferred food source for many filter feeding animals, including microscopic zooplankton. Green algae, particularly *Spirogyra*, *Chlorococcum*, *Closterium*, and *Volvox*, were common in Shadyside Park Lake, but the diversity of green algae was somewhat greater in Vulcan Lake. Life cycles and behavior of many species of green algae are not understood very well (Horne and Goldman, 1994).

Diatoms provide an important link in the food web of lakes and in processing certain minerals, especially silica. Several forms of diatoms were particularly abundant in Vulcan Lake, especially *Synedra*, *Fragillaria*, and *Navicula*. During the early summer, grazing pressure by zooplankton on diatoms and competition for food between

Figure 22. Structure of the planktonic community in combined epilimnion and metalimnion samples at Shadyside Park and Vulcan Lake, Madison County, Indiana, on August 6, 1996.

diatoms and bluegreen algae both increase. As a result, most species of diatoms disappear by the end of July (Lund, 1964; Heron, 1961). In contrast, the diatom *Fragillaria* commonly reproduces in fall and may be an indication of nutrient enrichment through sewage or polluted runoff (Williams, 1969). Diatoms are relatively heavy microorganisms because of their silica shell. In temperate lakes in late summer, heavier diatoms may sink out of surface waters, whereas more buoyant blue-green algae or swimming dinoflagellates may tend to dominate the surface community (Horne and Goldman, 1994). No spring or fall collections were taken in this study. For these reasons, the timing of the August sample may have underrepresented the number of diatoms in the lake, especially in the deeper Shadyside Park Lake.

Dinoflagellates are not preferred food for other animals and were uncommon in any of the study lakes. Dinoflagellates grow well under intense light conditions, but are poor competitors for food resources compared to most species of green and bluegreen algae. Reduced water clarity may limit dinoflagellate growth in Shadyside Park Lake. Lack of dinoflagellates in the samples may also reflect their life history. Dinoflagellates begin reproducing in late July and generally peak in abundance in November. Samples in this study were collected at the beginning of the growing season for dinoflagellates and may have underestimated population size.

Populations of the bluegreen algae may increase dramatically in late summer and fall in productive lakes, causing beneficial algae species and rooted plants to become less abundant. Several species of bluegreen algae, including *Mycrocystis* and *Anabaena*, and the diatom *Fragillaria* commonly occur in hardwater lakes with high alkalinity, which describes most Indiana lakes. However, an overabundance of bluegreen algae can create a nuisance in lakes used by humans. These species cause noxious blooms and high daytime pH levels in eutrophic lakes. Bluegreen algae may form dense mats across the surface that are unsightly, impede recreation, and shade out beneficial rooted plants. In addition, only a few aquatic animals eat bluegreen algae. Several bluegreen species found in the Anderson Park lakes can produce strains that cause unacceptable taste and odor in drinking water and are capable of causing poisoning deaths of fish and livestock under some circumstances (Lampert, 1987). Decomposition of large dying populations can consume oxygen and result in fish kills. The only naturally occurring control of bluegreen algae is competition between bluegreen species and cold temperatures or eventual consumption of critical nutrients.

A complex interaction of competing species with different capabilities control seasonal population dynamics of detrimental bluegreen algae. Species demonstrate particular behaviors that determine where in the water column or lake the species is most likely to occur. Life stages may have changing food or habitat requirements. Large blooms of some phytoplankton species can die out rapidly due to attacks by viruses or fungi.

The life cycle and behavior of different species can determine whether a population is present in the lake but not represented in the water column at a particular point in time. Diatoms multiply rapidly in cooler water during spring because the silica shell requires less energy to produce than the cellulose wall of other microscopic plants (Horne and Goldman, 1994). In contrast, bluegreen algae have a spore-like resting stage that overwinters in the sediments. During the spring, most bluegreen algae multiply slowly in colder water, but hatch from the sediments and rapidly reproduce in warmer water of summer through early fall. Green algae often dominate the summer plankton due to an ability to take up nutrients at low levels and maintain their position near the surface by swimming.

Mobility and rapid reproduction can create patches or layers of phytoplankton that may break up with currents and changing nutrient or light conditions. Daily migrations from deeper, darker water to sunlit surface waters occur for some bluegreen algae found in the Anderson lakes, including *Mycrocystis* and *Anabaena*. These species accumulate gas in their tissues, rising to the surface at night and sinking during mid-morning. This phenomenon may also explain why bluegreen algae were more common in deeper samples during mid-afternoon in August. They could have shown the reverse pattern if they were collected in the morning.

Human activities can provide favorable conditions for growth of detrimental bluegreen algae. Shifts in nutrient availability can alter the relative abundance of phytoplankton species. A few bluegreen species, including *Aphanizomenon* and *Anabaena*, are capable of using nitrogen gas from the atmosphere and so have an added advantage over green algae and other species of bluegreens, such as *Mycrocystis* and *Oscillatoria*, which must take nitrogen directly from the water (Horne, 1975). Therefore, nitrogen is not a limiting factor for bluegreens, and they can react dramatically to an increase in phosphorus. For this reason, *Aphanizomenon* populations may grow rapidly in spring and early summer and die out in mid- to late summer as necessary iron resources are depleted. By mid-summer, *Anabaena* starts to grow because death of floating *Aphanizomenon* allows more light to reach the less buoyant *Anabaena*. *Mycrocystis* peak from late August through October as ammonia becomes available from decomposition of dying plants and animals in deoxygenated sediments. Release of ammonia and phosphorus from the sediments during alternating calm and windy periods during late summer or at fall turnover can produce a significant bloom of *Mycrocystis*. Ammonia from other sources, such as manure application or inadequate sewage treatment, can also contribute to blooms of *Mycrocystis*.

4.2.3 ZOOPLANKTON

Zooplankton (microscopic “animals”) play a critical role in lake ecosystems by transferring energy from primary producers (plants) to larger organisms in the food web. Zooplankton are particularly important in the diet of young fish, including bass, bluegill, and other sport fish. Zooplankton were four to six times more abundant in Vulcan Lake compared to Shadyside Park Lake. Zooplankton populations commonly increase from late June to mid-July, then decrease dramatically until early September, when they begin to increase again and may nearly reach spring levels (Wright, 1965). Therefore, samples taken in August may have underestimated the actual zooplankton population in the lakes. Several phenomena may explain these patterns.

Zooplankton rise to the surface at night to feed on phytoplankton, but remain at deeper, darker levels during the day to avoid predators. The late summer sample was collected from offshore waters in the Anderson Park lakes during early afternoon when zooplankton are more likely to occur deeper in the water. A sample taken in nearshore waters at mid-morning may have caught zooplankton still feeding near the surface. These migrations tend to be most strong in clear lakes with high predation pressure from planktivorous adult shad and minnows and young fish of many species (Carpenter et al., 1987). Therefore, lower numbers of zooplankton in Shadyside Park Lake may have indicated greater predation pressure from fish than occurs in Vulcan Lake.

On the other hand, zooplankton avoid warm water during the day to reduce the physiological cost of high respiration rates. Zooplankton and fish commonly spend most of the day in deeper, cooler water and move into the upper, warmer water at night or for brief forays during the day. Warm temperatures at the surface of the Anderson Park lakes in late summer may have driven zooplankton to deeper water during the day. However, deeper cooler water in the summer contained very little, if any, oxygen and may not provide an adequate temperature refuge for zooplankton or fish.

Populations of different species of zooplankton peak at different times in the year due to food availability and competition. Two main peaks in abundance of the large predatory rotifer *Asplanchna* usually occur in early spring and autumn, according to research conducted on other lakes (Dumont, 1972). Smaller rotifers, such as *Keratella,* feed on phytoplankton and increase with plant growth through late summer. *Asplanchna* feeds mostly on *Keratella* and other small rotifers, as well as some phytoplankton. As *Asplanchna* populations increase, small rotifers decrease towards fall. In late fall, lower light and temperature levels inhibit plant growth and animal feeding rates decrease. As a result, the number of phytoplankton found in a liter of water may be nearly equal to or even less than the number of zooplankton during the winter.

The quality and quantity of food available for zooplankton grazing depends on the species composition of the phytoplankton community. Zooplankton feed by filtering the water. Small phytoplankton, including diatoms, small flagellates, and small green algae are preferred food. Zooplankton can die out when the phytoplankton community shifts to larger green algae, colonial and filamentous bluegreen algae or dinoflagellates (Russell et al., 1971; Reid, 1975). Examples of less palatable species that were found in the lakes include the filamentous bluegreen species *Oscillatoria* and large colonies of green algae *Volvox* and bluegreen *Microcystis*.

4.3 SHORELINE AND AQUATIC PLANTS

Plants require light for growth. Penetration of light into deeper water is directly related to water clarity. Competition between planktonic algae and beneficial plants is mediated by the amount of light available for rooted plant production. In general, rooted aquatic plants can grow to a depth that is about three times the Secchi depth (water clarity) measurement, while bluegreen algae are more tolerant of lower light levels. Therefore, submerged aquatic plants would be limited by light in Shadyside Park Lake to areas shallower than 12 ft, but could live at the bottom of Vulcan Lake. Because Shadyside lake originated as a deep steep-sided quarry, the shoreline contours do not provide extensive shallow areas for aquatic plant growth. As a result, the role of rooted plants in producing oxygen, reducing nutrients, and providing habitat available for aquatic animals may be severely limited in Shadyside Park Lake. Vulcan Lake is much shallower, supporting aquatic plant growth across much of its area.

Light appeared to be the primary factor controlling plant growth in the lakes. Aquatic plant distribution differed between the Shadyside Park Lake and Vulcan Lake. Extensive plant growth in Vulcan Lake and presence of an extensive vegetated buffer around the lake may enhance clarity in that water body. In mid to late summer of 1996, an extensive mat of Eurasian water milfoil (*Myriophyllum spicatum*) spread across most of the surface of Vulcan Lake. Aquatic plants were rare along the shoreline of Shadyside Park Lake.

The distribution of aquatic plants in Killbuck Creek is apparently controlled by riparian shading, stream bed material, and water velocity. Plants root better in soft muddy substrates than in hard rocky beds. Most aquatic plants are weakly constructed compared to land plants and prefer slow water or no flow. Aquatic plants were abundant on the streambed of Killbuck Creek in park areas downstream of the lake, but not in upstream areas. Downstream of the lake, Killbuck Creek is open to sunlight, has a soft bottom, and has fairly extensive network of side channels that are protected from fast flow. Upstream of the lakes, the creek has a dense riparian buffer of mature trees that shades the single deep channel that forms the creek. The bed consisted of sand and gravel. The study did not identify the reasons for the greater amount of sedimentation in the creek downstream of the lakes. Nutrient export from the lakes may also contribute to downstream plant growth.

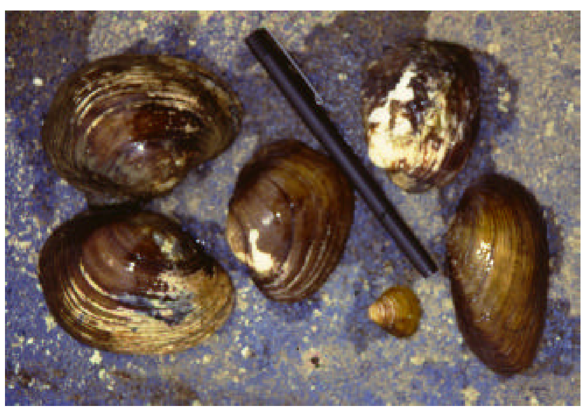
Killbuck Creek above Shadyside Park Lake.

Much of the shoreline around the Anderson lakes in this study supported natural vegetation with a diversity of native plants. These areas provide a variety of habitats adjacent to both flowing and still waters in the lakes and White River. For these reasons, the park areas provide an "island" of extremely valuable wildlife habitat in the midst of this expanding urban region. The areas did not appear to have extensive problems with exotic species that have invaded and degraded other lake ecosystems. This study did not include an intensive survey of exotic species. However, the following problematic species did not appear to exist in abundance: Amur honeysuckle (*Lonicera maackii*); multiflora rose (*Rosa multiflora*); purple loosestrife (*Lythrum salicaria*); and garlic mustard (*Alliaria officinalis*).

Presence of well-maintained recreational paths around the lakes provides visitors with an opportunity to appreciate the diverse plant community and wildlife habitat. These paths were always occupied with a number of recreational users during survey visits. Shoreline vegetation also supplied beneficial habitat to land-based and aquatic wildlife through overhanging roots and woody debris along much of the shoreline. Asphalt had been used to prevent further erosion in small areas where steep banks existed along the shoreline, particularly in the North Basin. Severe uncontrolled shoreline erosion was not evident around the study lakes. Trees and shrubs appeared to be providing adequate protection from erosion.

4.4 MUSSELS

Mussels require relatively good water quality to survive and generally cannot tolerate high rates of siltation or toxic chemicals. Although no intensive effort was made to sample mussels, shells from relatively recently deceased specimens of at least five species of mussels were found along Killbuck Creek immediately above Shadyside Park (Table 15). The paper pondshell (*Utterbackia imbecillis*) is widespread and locally abundant in lakes and sluggish mud-bottomed pools of creeks and rivers (Cummings and Mayer, 1992). The three-ridge (*Amblema plicata*) and plain pocketbook (*Lampsilis cardium)* are widespread and common throughout most of their ranges. The three-ridge has commercial value and may be declining in some smaller streams.



Mussels found in Killbuck Creek at C.R. 200 North.

Table 15. Mussels found in Killbuck Creek at Cross Street (C.R. 200N) on May 2, 1997. The size of the specimen and maximum known size for the species as listed in Cummings and Mayer, 1992, are given. Note that intensive sampling for size or taxa was not conducted.

Common name	Scientific name	specimen size	max size
Three ridge	*Amblema plicata*	2.75 in	7 in
Asiatic clam (exotic)	*Corbicula fluminea*	1 in	1.5 in
Plain pocketbook	*Lampsilis cardium*	3.75 in	7 in
Spike	*Elliptio dilatata*	3.5 in	5 in
Paper pondshell	*Utterbackia imbecillis*	2.5 in	4 in

The aforementioned species are all found in small creeks to larger rivers over mud, sand, and gravel. The spike (*Elliptio dilatata*) is widespread but sporadic in distribution and is listed as a species of special concern in Illinois. The type specimen photographed in the Field Guide to Freshwater Mussels of the Midwest was from Killbuck Creek. The Asiatic clam (*Corbicula fluminea*) is a widespread introduced (exotic) species.

4.5 FISH

Fisheries management reports published by IDNR describe Shadyside Park Lake as improved since the 1970s, but with questionable capacity as an improved sport fishery without further attention to water quality. In 1975, the sport fishery was considered “unsatisfactory and in need of immediate management.” The lake contained a large population of gizzard shad. Small white crappies and yellow perch were the principal game fish with few bluegill and largemouth bass. Selective eradication of gizzard shad and carp, was followed by restocking with adult white bass, channel catfish, and largemouth bass fingerlings in 1976. Fish barriers at the inlets and outlets, a minimum bass size limit of 14 inches, periodic stocking, and repeated monitoring were recommended to the Anderson Park Department.

Due to the importance of the lake for recreation, the DNR has continued to conduct fish management in Shadyside Park Lake, despite continuing limits imposed by reduced oxygenation in the lake during the summer. By 1991, the water body was described as providing one of the few desirable public fishing sites in Madison County and serving a large urban population as an accessible lake. Fish management reports during the 1990s indicated good growth rates and population structure for largemouth bass, but less success with bluegill.

Attempts to improve the sport fishery have met with some recent success. The DNR stocked 1,000 one inch fingerlings of hybrid striped bass in 1993, 1995, and 1997. Survival and growth of the 1995 stocked hybrid bass has been excellent. The hybrids tend to migrate great distances when current is present. The 1993 cohort was not found and may have left the lake during high water. Future years will show if the hybrid bass can compete with the established yellow bass. The apparent shortage of young gizzard shad in 1994 and 1996 may decrease survival in all bass, which prefer to prey on young shad.

The composition of the overall fish community suggests degradation in water quality over the past 20 years that was not necessarily reflected in some of the sport fish species (Table

16; Figure 23). The relative abundance of bass and sunfish species has changed little, showing a minor decrease from 48 to 42 percent. However, representation of catfish and sucker species has decreased dramatically as shad, carp, and other nongame species increased. Populations of species, such as shad and carp, that can interfere with other fish have stayed high. Competition with gizzard shad and limited spawning habitat were cited as reasons for lower numbers of large bluegill. Gizzard shad and suckers appeared to enter the lake during high water overflow from Killbuck Creek in spite of the existence of a two-inch mesh barrier. The introduction of yellow bass also apparently had a negative effect on the fishery, according to DNR reports.

Table 16. Relative abundance of fish groups caught in Shadyside Park Lake after a fisheries renovation in 1975 (1976, 1991, 1994, and 1996).

	1976	1991	1994	1996
Bass	48.4	45.2	42.4	51.6
Shad	0	38.9	29.2	31.5
Sucker	26.8	9.8	6.6	9.0
Other	2.2	6.9	20.6	6.5
Carp	0	0.6	0.9	1.0
Catfish	23.2	0.4	0.4	0.1

Particular species give a mixed indication of water quality changes. A total of 27 species have been collected in Shadyside Park Lake. These species indicated a gradual reversion to the less desirable species composition after a 1975 fisheries renovation (Table 17). The following species appear to have declined or disappeared from the lake: logperch, northern hog sucker, black crappie, bluntnose minnow, yellow bullhead, black bullhead, and possibly golden shiner. Logperch, brook silverside, and northern hog sucker are insectivorous, nest or attach eggs to clean gravel, and are moderately intolerant to pollution (Ohio EPA, 1987). The sudden decline in brook silverside in 1996 may also be a result of bass shifting their feeding from young shad to silverside. The other species listed are tolerant to pollution. Species which may be increasing include: gizzard shad, hybrid striped bass, yellow bass, and spotted sucker. Spotted suckers are gravel-nesting insectivores. Shad constitute a large proportion of the community numerically in the 1990s, while carp were at low numbers but constituted 10 to 14

Figure 23. Structure of the fish community in Shadyside Park, Madison County, Indiana, in 1976, 1991, 1994, and 1996 based on collections reported by the IDNR Fisheries Section.

Table 17. Fish species caught in Shadyside Park Lake after a fisheries renovation in 1975 (1976, 1991, 1994, and 1996).

		Total number				Percent of total			
Common name	Scientific name	1976	1991	1994	1996	1976	1991	1994	1996
Gizzard shad	*Dorosoma capedianum*		693	231	217		38.9	29.2	31.5
Brook silverside	*Labidesthes sicculus*		96	142	27		5.4	18	3.9
Yellow perch	*Perca flavescens*	1	6	17	14	0.4	0.3	2.2	2.0
Golden shiner	*Notemigonus crysoleucas*		5	3	1		0.3	0.4	0.1
Bluntnose	*Pimephales notatus*	5			3	1.8			0.4
Logperch	*Percina caprodes*		16		1		0.9		0.1
Common carp	*Cyprinus carpio*		11	7	7		0.6	0.9	1.0
Yellow bullhead	*Ameiurus natalis*		2				0.1		
Black bullhead	*Ictalurus melas*	62				22.1			
Channel catfish	*Ictalurus punctatus*	3	6	3	1	1.1	0.3	0.4	0.1
Northern hog sucker	*Hypentelium nigricans*		7				0.4		
Golden redhorse	*Moxostoma erythrurum*		2	2	5		0.1	0.3	0.7
Spotted sucker	*Minytrema melanops*		26	30	42		1.5	3.8	6.1
White sucker	*Catastomus commersoni*	75	138	20	15	26.8	7.8	2.5	2.2
Largemouth bass	*Micropterus salmoides*	115	388	115	126	41.1	21.8	14.6	18.3
Bluegill	*Lepomis macrochirus*	1	242	114	110	0.4	13.6	14.4	16.0
Yellow bass	*Morone mississippiensis*		52	86	86		2.9	10.9	12.5
Longear sunfish	*Lepomis megalotis*	5	88	10	12	1.8	4.9	1.3	1.7
Hybrid striped bass				4	21			0.5	3.0
White crappie	*Pomoxis annularis*	1	9	2		0.4	0.5	0.3	
White bass	*Roccus chrysops*	10	16	1		3.6	0.9	0.1	
Rock bass	*Ambloplites rupestris*		1	1	1		0.1	0.1	0.1
Hybrid sunfish			1	1			0.1	0.1	
Smallmouth bass	*Micropterus dolomieu*			1				0.1	
Black crappie	*Pomoxis nigromaculatus*		6				0.3		
Green sunfish	*Lepomis cyanellus*	2	1			0.7	0.1		
Redear	*Lepomis microlophus*	1				0.4			
Total		**281**	**1812**	**790**	**689**				
Species number		**12**	**22**	**19**	**17**				

percent of the community by weight in 1991, 1994, and 1996. Carp were observed vigorously spawning in the shallows of the North Basin during field work in August of 1996.

Water quality can have an indirect effect on survival and growth of desirable fish species. Turbidity (lower water clarity or light penetration) can limit sight feeding and can increase hybridization of species that select mates by sight. The incidence of hybrid sunfish suggests that water quality may be interfering with appropriate mate selection. Hybrid fish are generally less well adapted and can cause a decrease in survival and reproduction. Periodic fish kills can occur due to turnover of deoxygenated deep water in the spring or massive death and decomposition of algae. Periodic fish kills have occurred in the lake. Evidence of a fish kill was noted in numerous dead fish near the Shady Run inlet on May 20, 1998.

Competition between preferred prey and unpalatable bluegreen algae can reduce the availability of adequate food. Results from this study suggested that relatively small numbers of zooplankton may limit the growth of fish populations in the lakes. Diatoms are particularly important as a food resource for newly hatched fish fry in the spring. Diatoms were much more abundant in Vulcan Lake than in the Shadyside Park, possibly reflecting higher predation rates by fish in Shadyside Lake and presence of few fish in Vulcan Lake. Vulcan Lake is not hydrologically connected to a larger stream system or the White River like Shadyside Lake and is therefore more isolated from external sources of fish.

Species not native to a region can cause serious and nearly irreparable damage to biological communities. Introduced species that are predators can devastate native prey fish, as they often are not susceptible to native diseases or predators. When natural resource agencies introduce nonnative fish for recreational purposes, the potential impacts are usually carefully studied. Some exotics enter lakes by accident or by intentional release of aquarium fish with unpredictable and sometimes disastrous effects on other lake organisms. In August 1998, an exotic pacu, native to South America, was caught with chicken liver bait from Shadyside Lake in Anderson (IDNR Division of Fish & Wildlife, 1998). A professor of biology at Anderson University verified the identity of this rather large 6 ¼ pound (2.8 kg) fish. This fish was probably released from an aquarium after it grew too large and became unwanted. The likelihood of reproduction by this particular species is low, but release of any live fish into another water body should be strongly discouraged. Released fish can carry diseases that could become problematic for native fish.

4.6 WATERFOWL

Overabundant geese can create water quality and aesthetic problems. In some locations, high fecal coliform counts are attributed to geese. Goose manure can be objectionable to many park visitors. Other visitors enjoy feeding the geese and ducks, which encourages them to stay through the winter in large numbers. Park officials have taken several actions to reduce problems associated with geese. The city instituted an ordinance prohibiting the feeding of waterfowl in 1993 and removed most of the domestic waterfowl. Although some feeding of waterfowl is still occurring, DNR fisheries reports indicate a general reduction in unwanted waterfowl around the lakes.

Management of the landscape near the water may continue to attract geese. There were over a hundred waterfowl on the North Basin of Shadyside Park Lake during most of the survey days. The population consisted mostly of geese with some mallards. Most of these birds congregated at the beach near the inlet. Fewer geese were present on the South Basin. Presence of close-cropped grass near water along large beach areas has increased habitat for geese in many urban areas. In this set of lakes, geese were clearly congregated in areas that matched these characteristics. On days when water quality was surveyed for this study, a few mallards were seen flying across or swimming at Vulcan Lake. However, the lake has no areas that are mowed near the water and nuisance geese were not noted.

Waterfowl and eroded beach near the public parking area at Shadyside Park Lake.

5.0 IN-LAKE NUTRIENTS AND TROPHIC STATUS

Lakes created as gravel pits exhibit a different pattern of change from natural lakes in northern Indiana. Gravel pit lakes often have an initial period of very high water clarity and low productivity due to the low amount of organic material in the lake and high input from groundwater. Productivity increases over time from sedimentation and runoff in the watershed with the rate of increase dependent upon surrounding land use, topography, and soil types. Lack of more natural drainage patterns in artificial waterbodies can complicate lake development and management issues.

The Eutrophication Index, developed by IDEM, provides a convenient format for comparing and scoring various aspects of productivity and lake condition. This index ranges from 0 to 75 with the higher scores indicating more eutrophication, productivity, or lake aging. Eutrophication Index scores reflect the amount of nutrients, dissolved oxygen, water clarity, amount of phytoplankton, and relative abundance of bluegreen algae in the water column. Unlike most terrestrial ecosystems, where nitrogen tends to be the limiting agent, productivity in most freshwater ecosystems is limited by the amount of available phosphorus. Both green and bluegreen algae are dependent upon phosphorus present in water for growth. In contrast, several species of bluegreen algae function similarly to legumes; they are capable of fixing nitrogen from the air and do not rely on ammonia or nitrate in the water.

The Eutrophication Index was 22-27 for Shadyside Park Lake and 13 for Vulcan Lake (Table 18), placing them in the category of Class One lakes according to the IDEM lake classification system (IDEM, 1986). This category contains lakes that rarely support concentrations of macrophytes or algae that could impair attainable lake uses and for which chemical control is rarely necessary. The EI for Shadyside Lake borders on an intermediate (Class Two) condition, which contains most of the lakes in Indiana and generally describes lakes that are productive and very slowly aging with some impact from human activities. They may frequently support extensive concentrations of macrophytes or algae, but seldom to the extent that human use is impaired.

Table 18. Calculation of the Eutrophication Index (EI) in both basins of Shadyside Park Lake and in Vulcan Lake, Madison County, Indiana, on August 6, 1996. Points for nutrients are assigned for average concentration between surface and bottom samples. Estimated values are indicated with an asterisk (*).

Parameter	North	South	Vulcan
1. Total phosphorus (ppm)	**3**	**3**	**4**
2. Soluble phosphorus (ppm)	**1**	**3**	**1**
3. Organic nitrogen	**3**	**4**	**3**
4. Nitrate	**1**	**1**	**1**
5. Ammonia	**0**	**3**	**0**
6. DO (% saturation at 5 ft)	**4**	**0**	**0**
7. DO (% of column with 0.1 ppm)	**0**	**3**	**0**
8. Light penetration (Secchi)	**6**	**6**	**0**
9. Light transmission (estimated)	**4***	**4***	**3***
10. Total plankton / ml (to 1% light)	**0**	**0***	**1**
Bluegreen dominance	**0**	**0***	**0**
TOTAL SCORE	**22**	**27**	**13**

Overall water quality of the Anderson Park lakes was as good as or better than the average for similar sized impoundments in the same ecoregion of Indiana (Table 19). Statistics can be used to determine how different a lake measurement is from the same measurement in other lakes. The range that includes one standard deviation around the mean would statistically include 68% of the lakes in the study area. For instance, the average level of ammonia in these lakes was 1.35 mg/l. Because the standard deviation was 2.7, about two-thirds of the lakes could be expected to have an ammonia level in the range from 0 to 4 mg/l. Only two parameters for the Anderson lakes were outside one standard deviation around the mean. Water clarity was higher in Vulcan Lake, a positive sign. The depth to which oxygen extended was relatively shallow for the South Basin of Shadyside Lake, a sign of decreasing water quality. Only one other regional lake had less oxygen than the South Basin, suggesting unusually limiting conditions in this basin.

Table 19. Water quality during the summer in Anderson Park Lakes during 1996 compared to other lakes of similar size in Allen, Wells, and Wabash Counties, Indiana (IDEM, 1996). Lakes are listed from largest to smallest size. Levels are averages of surface and bottom readings. Parameters that indicate worse than average water quality are indicated with a box $\boxed{5}$. Values given are: size (acres); maximum depth (ft); total phosphorus (mg/l); dissolved phosphorus or SRP (mg/l); organic nitrogen, or TKN (mg/l); nitrate, or NO^3 (mg/l); ammonia, or NH^4 (mg/l); % of depth with 0.1ppm oxygen (oxic); and Eutrophication Index (EI). Counties indicated as: Allen (A), Wells (We), and Wabash (Wa).

lake	size (ac)	dept (ft)	tot-P (mg/l)	SRP (mg/l)	TKN (mg/l)	NO^3 (mg/l)	NH^4 (mg/l)	Secchi	oxic	EI
Everett[90] (A)	43	44	0.12	0.34	1.17	0.71	2.00	4.9	42	66
Fowler Park[92] (Wa)	50	40	0.06	0.02	0.80	2.30	0.27	8.4	77	11
French[90] (Wa)	na	72	0.85	0.48	9.71	6.02	8.83	7.2	40	56
Green Valley[91] (Wa)	50	18	0.60	0.04	2.04	0.47	0.43	2.6	56	59
Paintmill[90] (Wa)	50	30	0.09	0.05	1.92	0.28	0.37	1.3	80	29
South[90] (Wa)	45	60	0.03	0.01	2.03	3.35	0.30	2.6	100	19
Stick Pit 2[90] (Wa)	50	60	0.02	0.00	1.41	0.14	0.36	5.3	100	8
Kunkel[91] (We)	25	19	0.12	0.01	1.35	0.10	0.06	3.6	75	29
Moser[91] (We)	26	12	0.17	0.04	1.29	0.40	0.09	1.6	100	19
average	42	39	0.2	0.1	2.4	1.5	1.4	4.2	74	33
std dev	11	21	0.3	0.2	2.8	2.0	2.8	2.5	24	22
North Basin	20	14	0.18	0.03	0.9	0.15	0.2	$\boxed{3.5}$	100	22
South Basin	43	40	0.19	$\boxed{0.12}$	2.2	0.10	$\boxed{1.5}$	$\boxed{2.5}$	$\boxed{49}$	27
Vulcan Lake	9	10	$\boxed{0.37}$	0.03	1.1	0.15	0.1	**6.8**	100	13

Water quality in the lakes may produce aquatic plant growth that would interfere with recreational use in Shadyside Lake, but is more likely to create a problem in Vulcan Lake. Class One lakes rarely support concentrations of algae or macrophytes (larger plants) that could impair attainable lake uses and for which chemical control is necessary. Lakes characteristic of Class Two, possibly including Shadyside Lake, frequently support extensive concentrations of plants or algae but seldom to the extent that it interferes with human use. Although adequate levels of nutrients are present for plant growth, the depth and steep sides of Shadyside Lake preclude extensive growth of rooted plants. However, Vulcan Lake is shallow enough to provide adequate plant growth across much of the lake surface. In 1996, growth was severe enough at the surface to interfere with recreational boating and fishing.

5.1 RELATIONSHIP BETWEEN NUTRIENTS AND PRODUCTIVITY

Growth of plants and animals (productivity) in lakes is largely determined by relative amounts of phosphorus and nitrogen. Other nutrients are usually present in sufficient quantities and are a less decisive factor in regulating productivity of aquatic systems. Nitrogen, phosphorus and other nutrients can combine in different molecules, or forms. The form will determine how easy it is for plants to use, how toxic it is to other organisms, and how available it is from different sources. For instance, some forms of nutrients (ammonia, nitrate, and soluble phosphorus) are easier for plants to use and will produce a more immediate response in plant growth than other forms of the same nutrient. Nitrite is highly toxic, but also rapidly converted to other forms by bacteria. So this toxic form is usually not present in water at high levels.

The ratio of nitrogen to phosphorus indicates which nutrient is controlling productivity in a particular lake. Depending upon the species, algae generally require a ratio of total nitrogen to total phosphorus of 15:1 (U.S. EPA, 1980). Ratios of 10:1 or less indicate nitrogen limitation or overabundance of phosphorus. Adding concentrations for all forms of nitrogen in both basins of Shadyside Park Lake gives a total nitrogen concentration of 1.25-3.8 mg/l and total phosphorus concentration of 0.18-0.19 mg/l, as an average of surface and bottom measurements. Therefore, the ratio of total N to total P was 7:1 for the North Basin and 4:1 for Vulcan Lake, suggesting an overabundance of phosphorus relative to the amount of nitrogen in those waterbodies. However, in the South Basin, the ratio was 20:1, indicating a relative overabundance of nitrogen.

Available nutrients in the Anderson lakes are not at a level to suggest immediate problems with algae. In general, phosphorus limited systems (South Basin) will have lower algal growth. Water clarity problems are more likely to be caused by suspended sediment in these waters. In contrast, noxious bluegreen algae are favored by nitrogen limitation (North Basin and Vulcan Lake). These bluegreen algae can create mats which were evident at the edges of the North Basin and Vulcan Lake.

Bluegreen algae mats and bank erosion in the north basin of Shadyside Park Lake.

The distribution of nutrients through the water column affects the availability of nutrients for productivity and is correlated with other chemical characteristics in the lake. The average value between the surface and bottom for several parameters indicated somewhat poorer water quality than in other regional lakes. Those values were: 1) total phosphorus in Vulcan Lake; 2) soluble phosphorus and ammonia in the South Basin; and 3) water clarity in both Shadyside Park Lake basins. However, none of these values was outside one standard deviation in comparison to the other lakes in the region.

High levels of nutrients in deep water can indicate an ongoing or historical problem with nutrient inputs. In addition, nutrients in deep water will continue to recycle and cause water quality problems, even after watershed inputs have ceased. Total phosphorus was present at relatively high levels in deeper water of all Anderson Park lakes tested during the summer (Table 20; Figure 24). Soluble phosphorus, ammonia and organic nitrogen were fairly high in deeper water of the South Basin. Deepwater total phosphorus levels in Vulcan Lake were two to three times higher than in Shadyside Park Lake.

Table 20. Chemical levels at the surface and bottom of the Anderson Park lakes on August 6, 1996. Levels that would trigger a rating of "4" or more (poor water quality) on the Eutrophication Index (EI) are indicated with a box "$\boxed{}$". Ammonia (NH_3) , nitrate-nitrite (NO_3+NO_2), total phosphorus, ortho-phosphorus, and total Kjeldahl, or organic, nitrogen (TKN) are given in milligrams per liter. (ammonia, nitrate = nitrate+nitrite, total P = total phosphorus; ortho-P = ortho-phosphorus; TKN = total Kjeldahl nitrogen)

location	pH	ammonia	nitrate	total P	ortho-P	TKN
Vulcan surface	8.6	< 0.1	< 0.1	< 0.09	< 0.03	0.4
Vulcan bottom	7.8	< 0.1	0.2	$\boxed{0.64}$	< 0.03	1.8
South Basin surface	8.9	< 0.1	< 0.1	0.09	< 0.03	0.7
South Basin bottom	7.5	$\boxed{2.9}$	< 0.1	$\boxed{0.28}$	$\boxed{0.21}$	$\boxed{3.7}$
North Basin surface	8.6	< 0.1	< 0.1	0.15	< 0.03	0.8
North Basin bottom	7.7	0.3	0.2	$\boxed{0.21}$	< 0.03	1

Several observations from the Shadyside Park Lake suggest strong reducing conditions and no oxygen for extended periods of time at the bottom of the lake. The deepwater sample in the South Basin smelled of hydrogen sulfide and contained black muck, most likely containing ferrous sulfide. Sulfide can originate from: 1) the activity of sulfur bacteria that decompose organic matter and liberate hydrogen sulfide from proteins in plant or animal remains; 2) pollutants introduced by residential and industrial development; or 3) chemical reduction of sulfate present in the soil and groundwater. Hydrogen sulfide is poisonous to aerobic organisms because it inactivates enzymes required for respiration (Cole, 1983).

Figure 24. Nutrient levels at the surface and bottom in the North and South basins of Shadyside Park Lake and in Vulcan Lake, Madison County, Indiana, on August 6, 1996. Ammonia (NH_3), nitrate-nitrite (NO_3+NO_2), total phosphorus, ortho-phosphorus, and total Kjeldahl, or organic, nitrogen (TKN) are given in milligrams per liter. (ammonia, nitrate = nitrate+nitrite, total P = total phosphorus; ortho-P = ortho-phosphorus; TKN = total Kjeldahl nitrogen)

The shape of a lake and its surroundings can cause it to be meromictic, meaning that deep water in the lake remains at the bottom and does not participate in the annual mixing cycle. The lake has a long narrow shape, relatively great depth and is protected from wind by mature trees around much of the perimeter. As a result, deeper water may be devoid of oxygen throughout the year, severely limiting the habitat volume available to fish, particularly in the South Basin. Lakes can also stop mixing if road salts wash into the lake and increase the density of deeper waters. Presence of several major roads and highways near Shady Run and the lakes may be contributing to the lack of mixing.

5.2 TRIBUTARY SOURCES OF POLLUTION

While nutrients already present in the lake may be repeatedly cycled from internal sources, nutrients and sediments also continue to enter the lake from external sources via tributaries and overland flow. Shadyside Park Lake receives input to the North Basin from one small stream (Shady Run) that appears as intermittent flow on the topographic map. Observations through 1996 to 1998 suggest that the stream contains some water along the section between Hwy 9 and the outlet all year. However, water was slowly flowing in reverse from the lake into Shady Run during baseflow. Mining activities along Shady Run may be altering surface and subsurface hydrology. The soils map also indicates a number of disconnected drainageways with temporary flow throughout both watersheds. These do not appear on the topographic map.

Vulcan Lake receives overland flow. No inlets were indicated on the topographic map. However, a network of drainages leading into the north side of the lake was shown on the soils map. Observations on site did not reveal a direct channel connection between the drainages and the lake, as indicated on the soils map nor any other defined inlet. Mining activities from at least the 1930s to the 1980s probably changed drainage patterns repeatedly in the area around Vulcan Lake. Swales and stormdrains in the residential areas to the north of the lake probably also alter the natural overland flow patterns in the watershed.

Selected nutrients and chemical parameters were higher in tributaries around Shadyside Park Lake (Table 21; Figure 25) than would be expected in most Indiana streams (Table 22). Nitrates were high in stormflow samples from Killbuck Creek upstream and downstream of the lake and in Shady Run at Hwy 9. Total phosphorus and organic nitrogen (TKN) were relatively high only in baseflow samples in Shady Run at Hwy 9. Elevated levels of nitrates and to a lesser degree, organic nitrogen, in stormflows in Killbuck Creek and Shady Run suggest pollution through dissolved nutrients in runoff or groundwater rather than from soil erosion. High levels of nutrients in baseflow samples may indicate contamination through faulty septic systems, wildlife or pet waste, application of lawn or agricultural fertilizers, and groundwater flows. Black sludge was noted in the culvert at Hwy 9, indicating contamination from road runoff or underground connections to culverts. No livestock were observed in the watershed.

Table 21. Tributary water quality during baseflow on May 2, 1997, and stormflow on May 29, 1997, in tributaries to Shadyside Park Lake and a channel near Vulcan Lake (Madison County, Indiana). Numbers in boxes indicate readings that were above the range which would statistically include two-thirds of Indiana streams (within one standard deviation), as indicated in Table 20, for temperature (°F), dissolved oxygen saturation, pH, turbidity (NTU), conductivity (umhos/cm), total phosphorus (mg/l), nitrate (mg/l), organic nitrogen / TKN (mg/l), and ammonia (mg/l).

	Killbuck Creek				Shady Run				Vulcan
	@ North		@ Rose Rd		@ Hwy 9		@ outlet		@channel
	Base	storm	base	storm	base	storm	base	storm	base
Temperature	54	56.7	53	58	58	57	52	58.5	57
DOsaturation	99	71	89	76	104	80	96	66	93
pH	8.2	8	8.2	8	$\boxed{8.5}$	8.1	$\boxed{8.4}$	8.1	8.2
Turbidity	4.43	13.93	10.46	14.9	$\boxed{109.9}$	9.94	5.76	$\boxed{125.9}$	$\boxed{700}$
Conductivity	664	---	615	---	$\boxed{815}$	---	$\boxed{709}$	---	---
tot-phosphor	0.05	0.08	0.05	0.08	$\boxed{0.27}$	0.1	0.03	0.16	0.03
Nitrate	0.8	$\boxed{4.8}$	0.8	$\boxed{4.2}$	1.1	$\boxed{4.6}$	0.1	1.7	0.1
TKN	0.4	0.9	0.5	0.8	$\boxed{3.4}$	0.8	0.3	1.1	0.6
Ammonia	0.1	0.2	0.1	0.1	0.4	0.1	0.1	0.1	0.1

Table 22. Average and range within one standard deviation for the first 50 IDEM monitoring stations in 1991.

parameter	average	low	high
pH	7.5	6.6	8.3
turbidity (NTU)	11	4.5	17.5
conductivity (umhos/cm)	587	466	709
tot-phosphorus (mg/l)	0.09	0.01	0.17
nitrate (mg/l)	2.05	0.95	3.15
organic nitrogen / TKN (mg/l)	1.15	0.63	1.67
ammonia (mg/l)	0.24	0.02	0.46

Physical and chemical changes in water temperature, dissolved oxygen, and conductivity suggest that pollution associated with runoff may be negatively affecting aquatic animals in Shady Run and Shadyside Park Lake (Figure 26). Slight increases in temperature during stormflow readings may be an artifact of having taken the stormflow samples later in May when the air and water were seasonally warmer. However, animal life in the streams may be impaired by consistent decreases in oxygen saturation in Killbuck Creek and Shady Run from 90 to 100% during baseflow to 70 to 80% during

Figure 25. Nutrient levels, temperature, dissolved oxygen (DO) saturation, and turbidity in tributaries to Shadyside Park Lake during baseflow on May 2, 1997, and stormflow on May 29, 1997 and an isolated channel near Vulcan Lake, Madison County, Indiana. Ammonia (NH_3) , nitrate-nitrite (NO_3+NO_2), total phosphorus, ortho-phosphorus, total Kjeldahl, or organic, nitrogen (TKN), and dissolved oxygen are given in milligrams per liter. Turbidity is given in nephelometer turbidity units (NTU). (ammonia, nitrate = nitrate+nitrite, total P = total phosphorus; ortho-P = ortho-phosphorus; TKN = total Kjeldahl nitrogen)

Figure 26. Temperature and dissolved oxygen (DO) saturation, and turbidity in tributaries to Shadyside Park Lake during baseflow on May 2, 1997, and stormflow on May 29, 1997 and an isolated channel near Vulcan Lake, Madison County, Indiana. Dissolved oxygen (DO) is given in milligrams per liter.

stormflow. Nutrients, sediments, and other chemical runoff can cause a decrease in oxygen in water and remove it from use by other aquatic organisms. Low levels of oxygen in the lake may be related to organic matter and chemicals entering from the tributaries.

High conductivity readings may indicate elevated levels of dissolved solids and inorganic minerals that can come from wastewater or surface runoff (APHA 1989). Conductivity and pH were high in baseflow measurements from both sites on Shady Run. Conductivity was not measured in stormflow samples. Higher conductivity in watersheds with similar land use is usually strongly correlated with a larger drainage area (Cole 1983). However, conductivity in Shady Run was higher than in Killbuck Creek even though Killbuck Creek has a larger watershed. Conductivity in Shady Run was also high relative to other Indiana streams. These comparisons indicate that Shady Run may be transporting unusually high levels of chemical runoff, which could include salts or other materials that dissolve and ionize in water.

Black sludge in culvert on east side of Hwy 9 on May 29, 1997.

Sampling indicated few problems related to soil erosion and turbidity in Killbuck Creek but did show a potential need for erosion control in Shady Run (Figure 27). Water clarity was low and did not change significantly between stormflow and baseflow in Killbuck Creek. Even without an intensive sampling effort, numerous empty mussel shells representing at least five species were found along the banks of Killbuck Creek in May 1997. Two state endangered species of mussel have been found within the last decade in the creek. The stream bed in this area consisted of fairly sand, cobble, and clay with little embeddedness. These species cannot survive siltation and should be protected from increased degradation in water quality from soil erosion. Sedimentation in Shady Run was evident in high turbidity readings, embeddedness in the stream bed, and development of a sediment bar that extends 20 to 30 ft into the North Basin at the mouth of the stream. Water clarity was poor in Shady Run from baseflow samples at Hwy 9 and stormflow samples at the outlet.

Figure 27. Turbidity in tributaries to Shadyside Park Lake during baseflow on May 2, 1997, and stormflow on May 29, 1997 and an isolated channel near Vulcan Lake, Madison County, Indiana. Turbidity is given in nephelometer turbidity units (NTU).

Although sections of Shady Run are lined with trees, erosion was evident along much of the stream bank from the residential area east of Hwy 9 to the outlet. Conversations with residents indicated that the stream is relatively flashy with rapid peaks and high flood flows that frequently extend beyond the narrow low flow channel into the flood plain area. Residences are located fairly close to the channel east of Hwy 9. Drainage from the highway and adjacent ditches may alter flow and water quality in the stream channel.

Streambank erosion in residential area along Shady Run east of Hwy 9.

Between Hwy 9 and the outlet, mining and development activities have directly altered the stream channel and riparian zone with graded areas, unvegetated sections, spoil piles along the channel, and access roads. These earth moving activities may destabilize the channel configuration and cause increased sedimentation.

Crossing at sand and gravel mine over Shady Run west of Hwy 9.

Water quality of the channel near Vulcan Lake was within typical ranges. Turbidity in the channel sample was high, but may have been biased by mixing water with sediments during collection in the shallow channel area. No direct connection was noted between this channel and the lake, although the configuration would suggest that there has been a connection in the recent past. No stormflow samples were taken in this channel.

6.0 RECOMMENDED LAKE MANAGEMENT STRATEGIES

The IDEM has developed lake management categories that match with recommended strategies for improving water quality in lakes based on their size, depth, and Eutrophication Index (EI) score. The category that applies to Shadyside Park Lake is Group VI(A) lake. This lake has an intermediate surface area and depth and shows moderate to advanced eutrophication. Water quality problems are generally "not severe enough to warrant drastic restoration techniques" but the "main management priority, which will improve water quality most effectively on both a short and long term basis, is the limitation of nutrient inputs" (IDEM, 1986). Recommendations for this lake group are as follows:

1. Wastewater treatment
   a. Treatment plants for communities in the watershed, removal of phosphorus.
   b. Septic tank maintenance programs.
2. Land use practice and watershed management
   a. Shoreland corridors for agricultural areas adjacent to the lake and tributary streams.
   b. Protection of watershed wetland areas.
   c. Erosion control.
   d. Zoning and development regulation.
3. Restoration
   a. Nutrient inactivation.
   b. Selective discharge.
   c. Macrophyte harvesting.
   d. Chemical controls (algicides).

Although the management system was not designed to address very small lakes like Vulcan Lake, the category most closely matching the lake characteristics is Group V. This group consists of shallow lakes with high water quality. Some lakes in this grouping occupy former gravel pits, which accounts for their good water quality. Others are natural lakes with little human impact. Management priorities stress maintenance of present conditions. The natural and aesthetic values of the lake dictate desirability and degree of protection. Shallow lakes do not have a large volume of deep water to buffer pollutant response, so they tend to degrade quickly and dramatically from pollution. The management category matches the following strategies:

1. Government or private protection
   a. Acquisition of shoreland.
   b. Restricted shoreland development and use.
   c. Restricted recreational use.
   d. Maintenance of existing aesthetic qualities.
2. Educational programs for lake and area residents to increase awareness of the natural resource value of the lake.
3. Maintenance of water quality
   a. Wastewater treatment, including phosphorus removal at plants.
   b. Land use control in the watershed.
   c. Protection of watershed wetland areas.

The sections below will elaborate on these and other management strategies that would be pertinent to the Anderson Park lakes. Inclusion of these strategies does not necessarily constitute recommendation of their use, but rather the suggestion that they might be considered. Each possible action must be evaluated more thoroughly to determine its suitability under the present circumstances.

6.1 IN-LAKE IMPROVEMENTS IN WATER QUALITY

Most in-lake improvements in water quality are curative rather than preventative. By the time sediments and nutrients impair water quality, repairing the damage is usually more costly than preventative measures would have been. Water quality will continue to degrade if watershed inputs are not stopped. Once they become necessary, dredging and aquatic plant management will have to be repeated periodically. Artificial restoration methods such as aeration and alum treatments are also expensive and may require monitoring. By identifying watershed sources of sediment, encouraging appropriate land use, and properly maintaining sediment and stormwater detention basins, restorative measure should not need to be repeated.

6.1.1 SEDIMENT BASINS AND DREDGING

Development of a sediment basin within the Shady Run stream channel in the area just upstream of the inlet to the lake where materials mining is currently located would treat pollution from upstream activities. Earthmoving equipment that is currently involved in the mining could be used to create and maintain a sediment basin in the creek during mining operations. The area will presumably be converted to residential use after mining is complete. At that time, the sediment basin would continue to serve as an aesthetic amenity as well as being maintained to protect water quality in the downstream lakes. Design of the basin to include a pool and wetland complex would increase benefits to water quality, wildlife habitat, and aesthetic appeal. Construction of the basin would require a permit from the DNR for construction in a floodway through the Division of Water and may require permits from the Army Corps of Engineers under Section 404 of the Clean Water Act and IDEM under Section 401 Water Quality Certification. The Lake and River Enhancement program (LARE) that is administered by the DNR Division of Soil Conservation offers funding for design and construction of this type of project. Pre-applications for the program are due by January 31.

Due to the depth and steep sides of these former quarry pits, dredging of the whole lake is probably not feasible. Spot dredging may be useful, especially in the delta that has formed at the mouth of Shady Run. This action should be weighed against the option of allowing development of or planting a filtration wetland at the delta along the mouth of the inlet to Shady Run. The effect on recreational use and potential for flooding that may result from this delta should also be considered. Disposal of dredge spoil can be very cost-prohibitive in an urban area due to lack of nearby spoil deposit sites. However, the nearby mining operation will presumably be closed in the near future. When converting this land to other uses, major earthmoving will be required. Use of the dredge spoil from Shadyside Lake to amend the property across the road to the east during the conversion process may fulfill the need for a disposal site.

Delta of sediment at the mouth of Shady Run.

6.1.2 AQUATIC AND SHORELINE PLANT MANAGEMENT

Reshaping the shoreline in Shadyside Park Lake could provide additional shallow areas for wetland and aquatic plant development. In areas where the shoreline is accessible to heavy equipment, it could be graded back to create a shelf and then stabilized with emergent and submergent plants. These plants could provide many benefits, including: 1) increased oxygen through photosynthesis; 2) reduced nutrients by plant uptake; and 3) improved habitat for aquatic animals. The use of fiber rolls or stone instead of asphalt to control shoreline erosion would have fewer negative impacts on water quality and shoreline habitat.

There are several options for managing overabundant geese. Geese are difficult to permanently relocate. Eliminating geese by killing them can create a public outcry in urban areas. Managing the geese by understanding their behavior can be the most successful strategy. Geese prefer short-cropped grass next to water. A band of taller ornamental or native grasses and shrubs along the water will provide a behavioral barrier between water and land and will make the area less desirable for geese. Less mowing near the water would also reduce maintenance costs for the park. Reduction in numbers of geese will attract diverse species of beneficial ducks and other waterfowl.

Management of the area to prevent intrusion or expansion of exotic invasive species like Amur honeysuckle (*Lonicera maackii*), multiflora rose (*Rosa multiflora*), purple loosestrife (*Lythrum salicaria*) or garlic mustard (*Alliaria officinalis*) should continue. Maintenance or development of walking paths or access sites around the lake should include attention to erosion control and retention of a buffer zone of native vegetation along the water.

Interference of aquatic plants with recreational use should be monitored in all study lakes with particular attention to Vulcan Lake. If use of this lake by unmotorized boats is a priority, careful application of herbicides to clear access lanes or launching areas would be recommended. Control of mat-forming plants will allow more light to reach beneficial plant species growing in deeper water. Contact herbicides, such as granular 2,4-D (Aqua-Kleen ®, Weedtrine®) could be formulated and applied to selectively control plants that produce mats at the surface, such as Eurasian water milfoil or coontail. Due to the relatively small size of Vulcan Lake, the more expensive, but more longer-lasting herbicides such as fluridone (Sonar®) may be a reasonable option for selective control of milfoil. Rooted native plants that protect the bottom sediments and provide habitat for fish should remain in the lake. Application of herbicides in public waters requires a permit from the DNR through the Division of Fish & Wildlife.

6.1.3 AERATION

The depth and shape of the lake indicate a potential for deep cold areas that could provide temperature refuges for fish during the summer. Lakes formed by abandoned gravel pits can provide unusual cold water habitat in warmer climates. High oxygen levels down through colder depths during the 1970s could have supported sensitive species, such as trout, that require cold temperatures and high oxygen during the summer.

Redistribution of oxygen into deeper water would provide fish habitat and reduce water quality problems related to nutrients and hydrogen sulfide in deeper water. Use of an aerator to completely destratify the water column would distribute oxygen throughout the lake, but could also resuspend harmful levels of nutrients that may currently remain unmixed at the bottom of the lake. A more effective option might be hypolimnetic aeration in which the aeration tube runs from the top to the bottom of the lake without involving the surface layer of water. Oxygen is mixed only in the bottom layer of water and nutrients are contained in that layer. Nutrients from deeper water may also be less available to cause algal blooms in the lake, because they do not mix with surface waters where algae live.

However, presence of hydrogen sulfide in deep waters means that the immediate effect of aeration could be mixing of the poisonous gas throughout the water column, resulting in an extensive fish kill. Aeration may be used just near the surface to drive down the metalimnion (transition area between oxygenated and anoxic deeper water). Restocking after chemical stabilization might produce a viable fish community over the longer term. However, if the source of sulfur is from groundwater and basin geology, bacterial processing will likely continue as long as the lake stratifies in summer. Continuous aeration from surface to bottom would be required to prevent stratification.

Increased salinity from surface runoff can reduce or stop natural patterns of lake mixing due to increasing density of water. High chloride levels in groundwater wells around Anderson may indicate leaching of road salts into surface and underground water systems. Storage and use of road salts near lakes and their tributaries should be prohibited or carefully controlled. Where possible, sand or other substances that produce traction through mechanical means should be used instead of chemical substances that dissolve in water.

6.1.4 FISHERIES RENOVATION

Fisheries management could be employed in several stages, starting with habitat management and continuing with direct manipulation of the fish community. The DNR fisheries reports suggested a combination of the following management actions: removal of waterfowl and strict enforcement of the no feeding ordinance; installation of an aerator; stocking channel catfish and introducing a predator (e.g., hybrid striped bass) to utilize the forage base; and controlling erosion in the Shady Run watershed. Introduction of a predator would decrease the number of unwanted shad and other small nongame fish that may be competing for space and food with game fish and more desirable native species. Success of channel catfish stocking may be limited by lack of adequate shoreline habitat for nesting and deeper water habitat for foraging.

Due to uncontrolled waterway connections with Killbuck Creek and the White River, reentry of “trash” fish would probably follow another fisheries renovation that consisted of removing and restocking fish. The fish community would go through a degenerating cycle similar to what occurred after the 1975 renovation. Decreasing the spacing in the bars of the outlet screen may prevent larger unwanted competitor fish from entering and desirable striped bass from leaving the lake, but would also require more maintenance. Young hybrid striped bass could still escape.

Because Vulcan Lake was created as an isolated water body, the fishery should be assessed and successfully improved through stocking, if indicated by the survey. Invasion of the lake by destructive species, such as carp and shad, would be limited by the lack of access to other waters. The shallow depth will probably only support a fish community of warmwater species that are relatively tolerant to heat. Dissolved oxygen levels were high enough throughout the water column to support most warmwater species of sport fish.

Stocking of fish in the lake will continue, but at a reduced rate, until water quality and fish habitat improve through management actions. Should the city wish to pursue improvements in the lake, such as installation of an aerator, funding through the Indiana Waters Grant program from the IDNR Division of Outdoor Recreation may be available. Further information on this and other recreation programs may be obtained by calling 317-232-4070. Other funds for lake improvement related to control of sediment and nutrient inputs, such as construction of wetland filters, may be available from the IDNR Division of Soil Conservation through the Lake and River Enhancement program (LARE). Information on this program is available by calling 317-233-3870.

6.2 WATER QUALITY AND BIOLOGICAL MONITORING

Further water quality and biological monitoring could provide additional information on effects of seasonal changes, extreme weather, and rapidly developing land use. Seasonal readings with a Secchi disk in dry and wet years would inexpensively provide further information regarding the source of turbidity in the lakes. Involvement in the IDEM Volunteer Lake Monitoring program would consist of less than a half-hour at least once a year to collect a water sample and conduct a Secchi reading. The information produced could guide effective lake management by providing baseline information for determining the positive or negative impacts of land and water conservation in the park areas and surrounding watersheds. Sampling more often would increase the information available for diagnosis and management. Seasonal sampling would provide a more specific understanding of the dynamics between nutrients, sediments, and algal growth.

Certain aspects of the biological community in and around the lakes merit further attention. Continued periodic assessment of the fish community following water quality improvements could result in a more successful future for the fishery. The historical and current presence of numerous mussels in Killbuck Creek suggests that these populations should be monitored and may warrant additional protection from water quality degradation. Monitoring of aquatic insect communities in Shady Run and Killbuck Creek would provide ongoing information about water quality in those streams relative to land use changes in the watersheds.

6.3 FUTURE WATERSHED DEVELOPMENT

The dramatic increase in population in Anderson over the past 30 years has probably had a detrimental effect on water quality in the streams and impoundments in the area. If adequate land use management is not implemented, these waters will continue to degrade. The population of Anderson has increased by over 20 percent since 1960 from a population of 49,061 to 59,459 according to the 1990 census (US Census Bureau). Population density in the areas around the lakes under study was high or very high for the region. Rapid construction was very evident during the study period from 1996 to 1998. Several factors restrict or determine the most appropriate measures for improving water quality through watershed management. As urban areas convert from rural uses to urban uses, appropriate management measures will also change.

6.3.1 WATER QUALITY RESPONSE TO LAND USE CHANGES

The size of the watershed will affect the timing and magnitude of the response in the receiving water body to changes in land use and runoff events. The watershed areas are very different for the North and South Basins. Overland flow is the primary mode of sediment and nutrient transport in the South Basin where there is no well-defined channel. However, the hydrologic connection between the basins suggests that water quality in each basin will affect the other.

A ratio of lake surface area to watershed area that exceeds 100:1 indicates a strong tendency towards being a highly productive (eutrophic) water body (Horne and Goldman, 1994). The watershed ratio is 107 land acres to 1 water acre (107:1) for the North Basin. The large size of the watershed relative to the lake suggests that runoff from the watershed is an overwhelming influence on lake water quality. In addition, the lake probably has a fairly high flushing rate as it receives runoff following a storm event. Large scale changes to land use will have a major effect on water quality. Scattered and small conservation efforts will probably not change the lake significantly. However, if the watershed pollutants are controlled, the lake may improve relatively quickly through flushing.

Low ratios of watershed area to lake surface area generally indicate that in-lake processes would drive water quality with less direct contribution from the immediate watershed. The South Basin has a very low ratio of 8 watershed acres to 1 lake surface acre. This low ratio in the South Basin suggests that pollutants in the lake are unlikely to flush rapidly unless there is enough of a hydrologic connection to the North Basin that flow from that basin will dilute and remove contaminants. The relatively low watershed ratio for Vulcan Lake (35:1) also suggests that small changes in the watershed would be likely to have a more immediate or obvious effect on the lake. These lakes will take a long time to recover from nutrients and other pollutants that have already entered the system. Therefore, preventive measures are essential to avoid lasting damage or expensive remediation measures.

However, the strong relationship in both basins of Shadyside Park Lake between monthly precipitation and water clarity from 1975 to 1996 indicates that watershed land use significantly influences lake water quality. The connection between the North and South Basins probably contributes to the deterioration of the South Basin. Conversely, more dense urban development may have contributed a relatively larger pollutant load to the South Basin from this smaller area. Because there is no historical record of water quality in Vulcan Lake, no conclusions are possible regarding relationships between precipitation, runoff, and water quality.

6.3.2 PREVENTING EROSION AND RUNOFF IN DEVELOPED AREAS

Rural uses, such as agriculture and mining, are probably temporary in this rapidly urbanizing region, but should still be conducted with proper land management measures to reduce soil erosion and chemical runoff. In the Shadyside Lake watershed, the few remaining crop fields and a larger area that is currently undergoing mining will presumably be used for residential or park development in the near future. Mining currently covers about 95 acres in the North and 98 in the South watersheds. There are about 234 acres of crop fields and open space that may be developed in the North and 45 acres in the South watershed. These areas represent 42 percent of the each watershed. Protection of soils from erosion is critical along steeper slopes between Alexandria Pike and Lindberg Road (C.R. 100N) and along all drainage ways. The existence of an obvious sediment bar at the mouth of Shady Run in the North Basin suggests current and potential future problems for lake water quality if further erosion in the watershed is not controlled.

Developments around the lakes must use appropriate soil stabilization measures during and after construction to protect the lake water quality. Soils that underlay several subdivisions along Shady Run in the North Basin, including the Cross Lakes Luxury Apartments, are susceptible to severe erosion and caving. Maintenance of retention ponds and riparian areas along stream corridors in these developments will require adequate bank stabilization. An area undergoing earthmoving activities to the north of Lindbergh Road will disrupt a band of severely eroded Fox silt loam and Miami soils. Stability of these soils is critical for maintaining water quality in the South Basin of Shadyside Lake. Fragile soils encompass the headwaters and border the northern slopes of all drainageways leading into the Vulcan Lake area. Most of the area to the southwest of the water tower is currently forested and appears stable. However, protection against runoff and soil erosion may be critical in the subdivision at the southwest corner of the intersection at Rangeline Road and 10th Street. If the forested cover were removed, adequate protective measures would be necessary.

6.3.3 PROTECTING WILDLIFE HABITAT IN DEVELOPING AREAS

Rapid development emphasizes the importance of the Anderson city parks for conservation of wildlife habitat. The occurrence of rare species on nearby state park land indicates the potential for significant habitat development in the areas around the lakes. Wetland restoration may be possible in a few areas in the Shadyside Park watershed. During the recent mining operation, deposition of spoil piles along lower Shady Run may preclude wetland restoration due to radical changes in soils and topography along the stream banks. However, reshaping of mined land in the area adjacent to the lower section of Shady Run would provide an excellent opportunity for development of filtering wetlands and streamside habitat. Riparian areas may also be restored along headwaters of Shady Run in areas that are currently cropped or near the electrical substation between Hwy 9 and Lindberg Road (C.R. 100N). The area within the park along the east side of the lower part of the South Basin presents a more likely candidate for wetland restoration and protection of existing habitat

Incorporating forested landscapes into developments can increase property values, as well as improving wildlife habitat and water quality. Protection of forest along streams and drainage ways can reduce movement of sediment and nutrients into the water. Several reaches of stream bank are eroding along Shady Run and may require protection with bioengineered or rip rap materials. Understanding the relationship between development, runoff, and stream scour would be critical for designing effective streambank stabilization projects. Development of ordinances that require a vegetated setback from waterways and protect trees in riparian areas would significantly improve water quality without requiring expensive engineering solutions.

Residential development in the Vulcan Lake watershed has probably nearly concluded, assuming that abandoned mining areas remain under park ownership. Outside of the park, only a small wooded section (6 acres) of the forest that existed in 1939 remains in an area of recent housing development on the southeast side of Harrison and 10th streets. Another small grassy area of about 8 acres exists on the northwest corner of the park along the Harrison Street extension.

Soils along steep slopes between the developed areas and natural park areas near Vulcan Lake should be protected from erosion. Methods include maintaining current forested cover, planning trails or access roads to avoid exacerbating erosion, and controlling velocity of runoff into drainageways and ponded areas at the base of slopes. Use of vegetation to control erosion will also create a buffer zone for wildlife habitat in transition between developed areas and park land.

Opportunities for wetland restoration in the Vulcan Lake watershed are limited to 6 acres of wetland soils on the west side of the park and small forested pools at the base of the steep slopes along the northwest border of the park. Soil disturbance during gravel mining may limit the responsiveness of the larger area to restoration methods. However, the forested areas, nearby clearing, and Vulcan Lake itself provide a diverse mosaic of adjacent habitats that would theoretically support a variety of species. The diversity of flowering plants and trees in the forested area immediately around Vulcan Lake also presents an aesthetically pleasing landscape. These areas are rare in urban regions and should be protected for education, research, and recreational purposes. Placement of trails during park planning should divert human traffic from sensitive or rare species.

Establishment and maintenance of appropriate detention basins may reduce peak flows and scouring in channels. Developers of future subdivisions in the watershed should be encouraged to design detention ponds that contain more natural habitat features, including shallow vegetated shoreline zones. The creation of stormwater detention ponds in several of the subdivisions between Hwy 9 and Cross Street (C.R. 200 N) provides some benefits associated with wetlands.

Figure 28. Flood boundary and floodway map for areas around Shadyside Park Lake in Madison County, Indiana (Source: IDNR Division of Water).

Figure 29. Flood boundary and floodway map for areas around Vulcan Lake in Madison County, Indiana (Source: IDNR Division of Water).

Local officials can encourage proper floodplain management by adopting floodplain ordinances through the National Flood Insurance Program (NFIP). Both the City of Anderson and Madison County participate in the NFIP. The flood boundary and floodway maps include area to the east of Shadyside Park Lakes including the mouth of Shady Run (Figure 28) and to the north of Vulcan Lake (Figure 29). Participation in the NFIP is based on an agreement between local communities and the federal government which states that if a community will implement and enforce appropriate flood plain management practices, the federal government will make flood insurance available within the community as a financial protection against flood losses. Communities that participate in the NFIP regulate floodplain development through construction and building permits, and protect regulatory floodplains from encroachment. Information on programs administered by the IDNR Division of Water is available by calling 317-232-4160.

Trillium in the forested area to the north of Vulcan Lake.

7.0 PROJECT FUNDING

There are several potential sources of funding for completing projects to aid lake improvement. There are currently no state funding sources directly applicable for dredging in publicly accessible or private lakes. However, park improvement grants are available from the IDNR Division of Outdoor Recreation, the Flood Control Revolving Fund (I.C. 14-28-5) administered by the IDNR Division of Water provides funds for "removal of obstructions and accumulated debris from channels of streams" and other related floodway improvements, and the IDNR Division of Soil Conservation administers the Lake and River Enhancement program (LARE) that provides funding for control of sediment and nutrient inputs to public lakes. The deadline for preapplications to the LARE program is January 31. Preapplications are available from the DoSC at telephone 317-233-3870. Typical projects implemented through the LARE program in urbanized areas of an agricultural watershed include constructed wetlands for sediment and nutrient removal and bank stabilization.

8.0 CONCLUSION

The region around the White River through Anderson has a unique human and natural history. Mounds State Park commemorates a long history of human settlement in the area along the river. The streams and adjacent forested areas support rare species even though development has progressed rapidly in some areas. Sand and gravel mining operations have used resources generated by past glacial activity along the river, changed the present day landscape, and left water for recreation and conservation in their path. The City of Anderson has taken the initiative to protect remaining areas with natural and cultural value around the formerly mined areas. This study provides some information to indicate potential threats to the long-term viability of these resources and suggests changes to land use to protect these valuable resources.

8.0 ACKNOWLEDGEMENTS

This preliminary study could not have been completed without the generous contributions of many people. Craig Hinshaw and staff of the Indiana State Department of Health analyzed the water samples. Ed Braun from the IDNR Tri-lakes Fisheries Station provided fisheries surveys. Staff from the IDNR Division of Water assisted with reviews and information, including David Knipe, David Nance, and Jomary Crary. Ron Hellmich of the IDNR Division of Nature Preserves provided information from the Natural Heritage Database. The City of Anderson requested the study and Jim Haberek, Tamera Doty, and John Coffin provided information, maps, and review of the draft study. Melody Myers-Kinzie of Purdue University identified the mussel shells. The Madison County Soil and Water Conservation District (SWCD) reviewed the document and provided additional information.

9.0 LITERATURE CITED

Cummings, K.S., and C.A. Mayer. 1992. Field Guide to Freshwater Mussels of the Midwest. Manual 5. Illinois Natural History Survey, Champaign, Illinois. 194 pp.

Hill, P. 1996. 1996 Indiana erosion rates. Indiana Tx2000 Program. Division of Soil Conservation, Indiana Department of Natural Resources, West Lafayette, Indiana.

Horne, A.J., and C.R. Goldman. 1994. Limnology. 2nd Ed. McGraw-Hill, Inc., New York. 576 pp.

Moss, B. 1972. The influence of environmental factors on the distribution of freshwater algae: an experimental study. 1. Introduction and the influence of calcium concentration. J. Ecology 60:917-932.

Reid, P.C. 1975. Large scale changes in North Sea phytoplankton. Nature 257:217-219.

Russell, F.S., A.J. Southward, G.T. Boalch, and E.I. Butler. 1971. Changes in biological conditions in the English Channel off Plymouth during the last half-century. nature 234:468-470.

U.S. Department of Agriculture. 1967. Soil Survey – Madison County, Indiana. Soil Conservation Service, USDA.

Williams, W.D. 1969. Eutrophication of lakes. Proceedings of the Royal Society Victoria 83:17-26.

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March 2, 1999

To: Jim Haberek, Planning Department, The City of Anderson
Jim Norris, IDNR Resource Specialist / Madison County SWCD
Ed Braun, Division of Fish & Wildlife, IDNR
Michael Neyer, Division of Water, IDNR
Lee Bridges, IDEM / OWM
Gary Maners, NRCS
William Jones, Indiana University - SPEA
Anne Spacie, Purdue University
Tom McComish, Ball State University

From: Gwen White, Aquatic Biologist
tel. 317-233-5468; FAX 317-233-3882;
email: gwhite@dnr.state.in.us

RE: Review of "A Preliminary Study of Anderson Park Lakes"

Enclosed is a review copy of "A Preliminary Study of Anderson Park Lakes, Madison County, Indiana." In 1996, the Planning Department for the City of Anderson requested funding for a diagnostic study of several lakes in the municipal parks system. Due to a very competitive process in which only about one-third of the requests are funded, the study did not receive a formal grant through the Lake and River Enhancement program (LARE). However, staff in the Division of Soil Conservation conducted a preliminary study to assist the City of Anderson in understanding the history of these lakes and in developing management recommendations for lake and watershed management. This study was completed internally with agency resources.

Please review this draft, make suggestions concerning the content of the study, and forward your comments to me by **April 1, 1999.**

Thank you for your contributions to this study and assistance in the review process. We appreciate your interest in the T-by-2000 Lake and River Enhancement Program.

Enclosures

cc: Jim Ray, Chief, Land and Water Conservation